Reg. U. S. Pat. Off.

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ASTM BULLETIN

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This Issue Contains

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MISCELLANEOUS NEWS NOTES:

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DECEMBER—1950

No. 170

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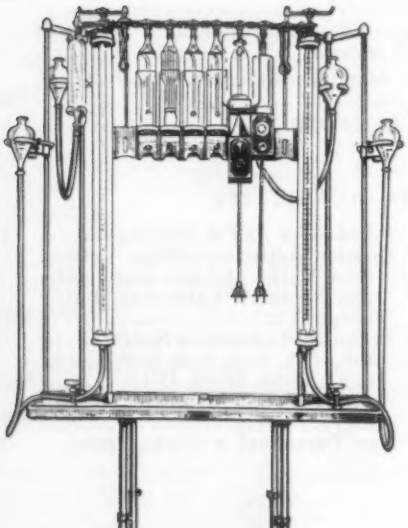

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All Fisher *Unitized* Gas-Analysis Apparatus may now be obtained either with or without glass ball-and-socket joints.

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ASTM BULLETIN

"Promotion of Knowledge of Materials of Engineering, and Standardization of Specifications and Methods of Testing"

TELEPHONE—Rittenhouse 6-5315 | R. E. Hess, Editor | R. J. Painter, Associate Editor | CABLE ADDRESS—TESTING, Philadelphia

Number 170 | DECEMBER, 1950

Important New Publications Issued

1950 Volume on Chemical Analysis of Metals, Manual on Measurement and Sampling of Petroleum Products, Examples of Important Industrial Books of Widespread Service

No matter how hard and efficiently the members and our technical committees may work in establishing adequate standards and promoting authoritative knowledge of materials through extensive research work, the results of the hundreds of cooperative projects would be rather inconsequential if they were not made available to all those concerned with the particular subject or allied subjects covered. This is the basic reason why the ASTM publication program is important.

To be sure, the financial returns from the widespread sale of so many books is important too; in fact, with the income from sales making up more than half of the Society's income-budget, the financial returns are vital in underwriting new publications. This is a continuing process. Wider sales of publications mean a broader base of financial operations and ability to carry through successfully and underwrite expanded work.

But if the maximum benefits are to come from the intensive efforts of so many hundreds of the country's leading authorities serving on ASTM technical committees, then the results of their manifold skills and deliberations must be made available, as widespread as possible and at the same time efforts must be made to see that the results are applied in the practical operations of everyday business. (Publications are vital in both aspects.) In other words, the standard specifications and tests must be used in designing, producing, and using materials and products; both the standards and research data must be used in developing new and improved materials and products.

While it is not the purpose of these few paragraphs, introductory to descriptions of certain important new publications, to detail the philosophy and mechanics of ASTM publication activities, it is always in order to remind our readers and ourselves that the books and the papers we publish are the result in most cases of cooperative effort. Even a paper by a single author involves cooperation, as the acknowledgment frequently attests. Furthermore, this paper will have been reviewed before it is accepted by the Society by other competent authorities who very frequently offer some very pertinent and constructive suggestions. The mere process of editing and putting the material in printed form represents the cooperation of many.

A symposium or special technical publication involving groups of papers or reports frequently is the result of the careful deliberations of a special symposium committee. New information is desired; also, the conclusions drawn from the facts reported must be logical.

It is hardly to be expected that the thousands who purchase ASTM books will need or even want to know of the background leading up to the final publication save to know that the work is authoritative and carefully produced. It is reassuring to know that under the careful supervision of the Society's Committee on Papers and Publications, with the cooperation of hundreds of the members, the results of our technical committee work and of so much important research work carried on in industry are so reliably presented in the Society's publications, to make these handbooks of industry.

The Standards, papers, and other publications are not necessarily final and in this respect they serve a most important purpose in stimulating others to contribute their ideas and experience and opinions in order that the value of the publications may be enhanced and augmented. New procedures may be offered for consideration as Standards, or discussions, or new papers offered for publication.

Every Society meeting is a forum and the Society itself is a forum, for the presentation of viewpoints and opinions on the subjects encompassed.

From all of this, the ASTM publications emerge to serve American Industry

1950 Volume on Chemical Analysis of Metals

Replacing the 1946 edition, the new 1950 book of ASTM Methods for Chemical Analysis of Metals is a greatly expanded volume. It is the culmination of intensive work through many months by ASTM Committee E-3 on Chemical Analysis of Metals and the Headquarters Staff. The membership of Committee E-3 (over 100) includes many of the leading technologists in this field. The new edition provides in their latest re-edited form all of the previous methods and it is supplemented by many new testing procedures which the committee has studied and improved, and which have subsequently been approved by the Society.

Now containing 39 extensive standards, covered in 486 pages, the publication is the *only* one where these chemical methods appear *together* in a convenient book form. The newer methods included take advantage of shorter procedures which have been developed and also cover additional metals. It is also worth noting that the several spectrochemical methods included were prepared by Committee E-2 on Emission Spectroscopy.

Some of those metals and alloys covered in the new edition appear below.

Ferrous Metals.—Steel; cast iron; open-hearth iron; and wrought iron.

Ferro-Alloys.—Ferrosilicon; Ferromanganese, silicomanganese, and manganese-silicon; ferrochromium; ferrovanadium; ferrotungsten and tungsten metal; and ferromolybdenum.

Nickel-Chromium-Iron Alloys.—Nickel and nickel-copper alloys.

Copper and Copper-Base Alloys.—Copper-nickel and copper-nickel-zinc alloys; brasses; special brasses and bronze; sulfur in special brasses and bronzes; copper and copper-base alloys; and copper.

Aluminum and Aluminum-Base Alloys

Magnesium and Magnesium-Base Alloys

Lead, Tin Antimony, and Their Alloys.—Antimony metal; pig lead; lead- and tin-base solder metal; white metal bearing alloys; and lead, tin, antimony, and their alloys.

Silver Solders

Zinc.—Slab zinc (spelter); determination of iron in slab zinc (spelter); polarographic determination of lead and cadmium in zinc; zinc-base die-casting alloys; and aluminum in zinc-base die-casting alloys.

Spectrochemical Analysis Methods.—Tin alloys for minor constituents and impurities; zinc for lead, iron, and cadmium; and zinc-alloy die castings for minor constituents and impurities.

To make the book of maximum service, there has been included a very detailed index. This index lists each method and procedure under at least two broad headings—the material covered and the substance being determined. Also, all methods in certain special classes such as photometric and electrolytic are so listed. No effort has been spared to make this index in the 1950 volume complete.

Besides recommended practices, for apparatus and reagents, photometric analysis, and for designating significant places in specified limiting values, there are sampling methods on steel and iron, ferrous alloys, wrought non-ferrous alloys, and cast non-ferrous metals and alloys.

For ease in recording special notes on various methods and procedures, there has been prepared, at the request of a number of individuals, a limited number of copies with interleaved blank pages. In this edition, aggregating about 1000 pages, there is a blank note page facing each page of type.

The 1950 edition of Chemical Analysis of Metals (cloth bound) is \$6.50. ASTM *members can obtain any number of copies at* \$4.50. The interleaved copies are \$9.00; to members \$7.00.

Measurement and Sampling of Petroleum

Now available is the Manual on Measuring and Sampling of Petroleum and Petroleum Products. The oil measurement standards included in the manual should fulfill a need in the petroleum industry for adequate proper standards and the best measurement practice.

They were developed by Committee D-2 on Petroleum Products and Lubricants and represent the result of ten years of investigation and research by its Division II. All available published material was examined as well as the variety of practices which have been in use. The comments and assistance of the Institute of Petroleum (England) were elicited. It is believed that the ASTM Manual represents the best and most accurate measurement practices in use today.

The care with which they have been prepared and the fact that representatives from 64 oil companies and an equal number from petroleum products consumers and general interests group approved this manual without dissenting vote should be strong reasons for their acceptance by the entire petroleum industry and by purchasers of oil in bulk.

More specifically, the manual will be most useful to the producer in the field or at the tank farm, to transportation men engaged in pipeline, tanker, barge, tank-car and tank-truck operations, to the refiner, to sales departments, and bulk storage operators, and to the many and varied consumers of petroleum products, who receive or store bulk shipments of one or more of them.

The manual is profusely illustrated. It contains many photographs and illustrations that show the latest types of apparatus for gaging, temperature measurement, and sampling. The methods are written concisely and in a simple style that is sufficiently detailed to enable the gager or sampler to proceed without further instructions.

The methods include: Tentative Method of Gaging Petroleum and Petroleum Products (D 1085), Method of Measuring the Temperature of Petroleum and Petroleum Products (D 1086), Tentative Recommended Practice for Volume Calculations and Corrections in the Measurement of Petroleum and Petroleum Products (D 1087), The Standard Method of Test for Gravity (D 287), The Tentative Method of Test for Water and Sediment (D 96), and The Tentative Method of Sampling Petroleum and Petroleum Products (D 270). A proposed method for sampling liquefied petroleum gases is also included.

The 132-page, heavy paper-bound book is \$2. Price to members is \$1.50. For cloth-bound book add 65 cents to above prices.

AN IMPORTANT ASSET

of membership is not only to receive the Society's regular publications, but to purchase at reduced prices one or more copies of any of the books which are on sale. It can be seen that this may result in considerable savings. For example, if a member wants ten copies of the new Volume on Methods for Chemical Analysis of Metals he would, by taking advantage of the members' price, save \$20. Virtually every publication issued by the Society is available to members at prices lower than the list; members can also procure *extra* copies of the regular publications at lower-than-list prices.

Physical Constants of Hydrocarbons

ROBERT MATTESON has compiled extensive tables which include most of the physical constants of hydrocarbons (boiling below 350 F.) which would be valuable to testing engineers and others concerned with the natural gasoline, synthetic rubber, industrial aromatics, and gaseous fuels industries. The group working with Mr. Matteson was formally organized by Technical Committee H on Light Hydrocarbons of ASTM Committee D-2 on Petroleum Products and the group was comprised of representatives from Shell Development Co., Union Oil Co. of California, and California Research Corp. Members are probably well aware of *Research Project No. 44* which was sponsored by the A.P.I and which resulted in tables of hydrocarbon constants similar to these of Mr. Matteson's group. However, the question of possible duplication was studied at the beginning of the project and the new work was conducted so that the two sets of tables would supplement each other rather than duplicate.

Six classes of hydrocarbons are covered in the tables, including paraffins, mono-olefins, di-olefins, acetylenes and naphthenes, and aromatics. Only those compounds having good freezing-point data were included in the compounds tabulated, on the assumption that others had not been prepared in sufficient purity Experimental data from the literature, when available, were used and bibliographical references and keys were prepared to show sources of the data used. In some cases it was necessary to estimate. Specifically, the tables include: Name of Compound, Formula, Molecular Weight, Boiling Point, Vapor Pressure, Freezing Point, the three Critical Constants, Liquid Densities (in four systems of units), Gas Density (in three forms), Specific Heats (at constant pressure and constant volume), Ratios of specific heats and liquid Specific Heats, gross and net Calorific Values, Heats of Vaporization, Refractive Index at two temperatures, Air Required for Combustion, Inflammability Limits, Aniline point, and Octane Number by two methods. The data on 225 compounds are included.

A guiding principle in the preparation of the ASTM tables has been that the values included must be consistent with the A.P.I.'s *Research Project No. 44* tables. In a section which precedes the tables, pertinent comments and details on the values used are given for each of the properties included.

The values included in the tables represent what are thought to be the best values appearing in the literature up to May, 1950; it is planned to keep the tables up to date by having a small working group from Technical Committee H be alert for new data and issue complete revisions about once every five years.

Mr. Matteson was assisted greatly by George R. Lake of the Union Oil Co. of California, C. O. Hurd of Shell Development Co., and W.S. Hanna of the California Research Corp.

The 16-page group of tables on Physical Constants of Hydrocarbons Boiling Below 350 F. is $1.00, with the special price to members—75 cents.

New Edition of Petroleum Standards Compilation

THE 1950 revision of the Compilation on Petroleum Products has been released and, as in the past, petroleum chemists, purchasing agents, sales engineers, and engineers in the petroleum field, the automotive, aircraft, tractor, railway, and other industries, will all find it to be of even greater use than previous editions.

The D-2 compilation of ASTM Specifications, Tests, and Definitions Covering Petroleum Products and Lubricants is one of the most widely distributed ASTM publications. It provides in compact form all of the ASTM standards in this field. The test methods for knock rating of engine fuels are not included in this compilation but are issued in a special volume. A new booklet which contains standards for measuring and pumping petroleum is also issued separately. (See article which appears on page 5.)

The book has been issued annualiy since 1927 and each new edition contains considerably more new material. Committee D-2, its sponsor, can look with pride on its contents—over 100 test methods, numerous specifications, lists of definitions of terms relating to petroleum, and to rheological properties, and a recommended practice for designating significant places in specified limiting values.

The several appendices include Hydrocarbon Type Analyses of Diesel Fuels by Silica Gel Adsorption, Bromine Number of Petroleum Distillates by Color Indicator and Electrometric Methods, Refractive Index and Refractive Dispersion of Hydrocarbon Liquids, Density of Knock Test Standard Normal Heptane and *Iso*octane, Pour Stability Characteristics of Winter Grade Motor Oils, Reduced Pressure Distillation of Petroleum Products, and Proposed Definitions and Specifications for Tractor Fuels.

Regulations covering the Committee D-2 on Petroleum Products and the latest D-2 annual report are also included.

The 780-page compilation is $5.50; to ASTM members the price is $4.25. For cloth bound copies, the price is an additional 65 cents.

Plasticity and Creep of Metals

Pacific Area Meeting Publication Has Valuable Papers

RECENTLY published is a new ASTM Symposium on Plasticity and Creep of Metals.

The significance of this symposium's topic can be fully appreciated by read-

"Martensite—As Quenched Showing Retained Austenite"

Second prize-winning electron micrograph, in the Seventh ASTM Photograpic Exhibit, by W. L. Grube, General Motors Corp., Research Laboratories Div. Magnification: electronic 3,500X, original photograph 25,000X. Reduced to about three-fifth size in printing.

ing some of the comments by John E. Dorn, Professor of Metallurgy, University of California, in his introduction to the symposium:

"Engineering interest in the plastic deformation and flow of metals originated during prehistoric times when our ancestors first began to hammer and forge metals into shape. The art developed leisurely over the ages. During the nineteenth century, however, industrial activities in forming metals and in the application of metals to elevated temperature service stimulated not only the art of metal forming but also the science of plasticity of metals. During this time the fundamental facts concerning the conditions under which plastic deformation begins were studied by St. Venaut, Tresca, Föppl, Guest and others. In the early quarter of the twentieth century this interest increased at an exponential rate and appreciable progress was made by such engineers as Ludwik, von Kármán, Lode, Ros, Eichinger, Taylor, and Quinney in uncovering the gross relationships between stress and plastic strain. In spite of this fact the knowledge on plastic deformation and flow of metals was found to be inadequate for the needs of production and use of materials for the Second World War. Extensive investigation into these fields were sponsored by the various industries, governmental agencies and the armed forces over 1941 to 1945. Methods of analysis and procedures of application of theory to engineering practice were developed and new technological advances in the art were made. At the close of World War II many engineers entertained the thought that a decrease in the research and development activities on plastic deformation and flow might be expected in consequence of reduced sponsorship of investigations in this field resulting from the decreased urgency and needs. But the lessons learned in World War II concerning the benefits to be derived from research and development and the ever increasing demands for knowledge on plastic deformation, flow, and creep of metals stimulated ever greater activity in this field.

"Although progress has been made in uncovering some of the basic factors involved in plastic deformation, much yet remains to be done before we can approach the subject with the same confidence we now have regarding elastic deformations. One source of difficulty arises from the fact that the shear distortion energy hypothesis for yielding of isotropic materials is known to be only a first approximation. It has been suggested that yielding is a function of both the quadratic and cubic invariants of the deviator stresses, but this hypothesis has not yet been subjected to critical experimental test. Another difficulty arises from the fact that most existing theories on plastic deformation are predicated on the assumption that the material is isotropic whereas the actual facts reveal that most wrought metals are anisotropic. In their paper on 'The Experimental Exploration of Plastic Flow in Sheet Metals' Jackson and Lankford have proposed a simple theory for plastic flow of anisotropic sheet metals based on the assumptions that the coefficients of anisotropy are invariant with strain and that the strain hardening is based on the shear distortion energy principle. Experimental investigations have shown that this theory is useful under conditions wherein the assumptions are valid.

"One of the major objectives of investigations on plastic deformation of metals in the analytical determination of forces involved in forming parts, and the evaluation from simple tests data such as the tension test the limit to which metal parts can be formed without introducing plastic buckling, local plastic flow or necking, and fracturing. In many problems the analytical difficulties of achieving a complete solution to such problems become almost insurmountable. In consequence, the analyses of these problems are frequently obtained by compounding good engineering judgment with the purely analytical approach. The success of such analyses is clearly revealed in Schroeder's paper on 'Forming Parameters and Criteria for Design and Production.'

"Increasing demands for high temperature resistant materials have placed ever increasing importance on the creep properties of metals. Creep is usually determined under conditions of tensile loading and it therefore becomes necessary to be able to predict the creep rates which may be expected in service under more general conditions of combined stressing. Cross and Jackson have illustrated in their paper on 'The Use of Creep Data in Design' the procedure which can be used to predict the creep rates of isotropic materials under combined stressing from the tensile creep data.

"Creep investigations are not only difficult to conduct accurately but are also time-consuming and expensive. The creep rates of metals are very sensitive to many factors which modify the structure so minutely as to escape x-ray and metallographic detection. Consequently, the entire production history of metals plays a significant role in determining their creep properties. The paper by Freeman, Fry, Reynolds, and White on 'Super Creep-Resistant Alloys' shows that considerable progress has been made in the detection of many factors that affect the creep-resistance of alloys but that much yet remains to be accomplished in order to permit a rational approach to the development of metals for high temperature service."

The papers (described above) and discussions in this Symposium on Plasticity and Creep of Metals were presented at the First Pacific Area National Meeting of ASTM in San Francisco last October. All papers, of course, present valuable data; there are numerous curves, diagrams, photographs, and working equations. Adequate references have been included. The 70-page "Symposium on Plasticity and Creep of Metals," *STP No. 107*, is $1.50; special price for members is $1.15.

WANTED: Copies of Back ASTM Proceedings and Other Technical Publications

So that ASTM Headquarters can fill orders and requests for complete sets of the *Proceedings* or for various earlier editions, and also supply some of the technical symposiums and special books issued years ago, an attempt is made to keep a reasonable stock of the books on hand. Yet inevitably our stock of some of the books becomes exhausted, and an appeal is now being made to the membership so that our stock of a number of these books might be replenished.

Proceedings:

It is desired to procure back copies of the following volumes of *Proceedings*. The Society will pay $3.50 per part or per volume for those before 1940, and $5 per volume for those carrying a 1940 date or later.

1901	1924 (Part 2)
1902	1933 (Part 2)
1903	1934 (Parts 1 and 2)
1912	1935 (Part 2)
1917 (Part 2)	1940
1919 (Part 2)	1942
1921	

Obviously the books, *Proceedings*, or Technical publications must be in reasonably good condition since they will be for resale. Also since only a limited number of copies of each volume will be purchased, members may wish to contact Headquarters by letter before shipping the books to us.

Technical Symposiums:

Even though books may have been printed five, ten, or even twenty years ago, we have continuing requests for some of them and the Society therefore would like to procure a few copies of the publications listed below. Members who have any of these books and who may care to dispose of them will be paid the indicated prices. While it is doubtful that members will wish to dispose of some of these publications, a few of the books may have outlived their usefulness for the respective members but would be useful and serviceable for others whose requests are on file.

Compilation of Available High-Temperature Creep Characteris-

tics of Metals and Alloys. STP 37. (1938)	$5.00
Symposium on Mildew Resistance. STP 57. (1943)	0.50
Report on Behavior of Ferritic Steels at Low Temperatures, by H. W. Gillett and F. T. McGuire. (Part I, text. Part II, illustrations.) STP 63. (1945)	2.00
A List of Alloys, by William Campbell (1930)	1.00
Symposium on Impact Testing (1938)	1.00
ymposium on Wear of Metals. STP 30. (1937)	1.00
ymposium on Hardness Testing	0.50
Symposium on Radiography and X-Ray Diffraction. STP 28. (1936)	2.00
Symposium on Corrosion Testing Procedures. STP 32. (1937)	1.00

100,000-Hr. Rupture Data for Wrought Steels

THERE has been a great deal of interest, particularly on the part of the steam design engineers, in 100,000-hr. rupture data, which were not included in the "Report on the Strength of Wrought Steels at Elevated Temperatures" because of the relative scarcity of the data. Subsequent to publication of the report, in May the authors prepared a tabulation of data for rupture strength of wrought steels at a rupture time of 100,000 hr. These data are shown in the accompanying table with the reference sources given as footnotes.

This 110-page "Report on the Strength of Wrought Steels" (Heger-Miller) was issued under the auspices of the joint ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals. It is a graphical presentation of information on tensile, creep, and rupture properties of wrought steels at elevated temperatures. Price is $3; to ASTM and ASME Members, $2.25.

Clarification

The errata notice which appeared on p. 15 of the October ASTM BULLETIN contained a reference to the curve of rupture strength *versus* temperature for the 2.25 per cent chromium-1.0 per cent molybdenum alloy which appears on p. 4 of the Report. The *entire* curve should be shifted 100 F. to the right. For example, the rupture strength value shown for a temperature of 900 F. is actually the rupture strength at 1000 F., the rupture strength value shown at 1000 F. is the 1100 F. value, etc.

TABLE I.—RUPTURE STRENGTH (PSI.) OF WROUGHT STEELS FOR A RUPTURE TIME OF 100,000 HR.

Alloy	Temperature, deg. Fahr.							
	900	1000	1100	1200	1300	1400	1500	1600
Carbon steel	...	2 800[a]	...	600[a]	410[b]	180[b]	...	...
0.5 Mo	27 500[c]	9 100[c]	...	...	...	...	...	...
	31 000[c]	11 700[c]	...	...	...	...	...	...
	50 000[d]	12 000[d]	...	...	...	...	...	...
	25 000[d]	8 800[d]	...	...	...	...	...	...
	38 000[d]	6 800[a]	3 150[a]	1 800[a]	525[b]	140[b]	...	...
	28 000[d]	...	...	...	...	...	...	...
	28 000[e]	9 000[e]	2 700[e]	...	...	...	...	...
0.5 Cr - 0.5 Mo	34 000[f]	16 500[f]	...	...	...	...	...	...
	39 000[f]	14 000[f]	...	...	...	...	...	...
	29 000[f]	11 000[f]	...	...	...	...	...	...
	46 000[f]	10 000[f]	...	...	...	...	...	...
	31 000[f]	...	...	...	...	...	...	...
	29 000[f]	...	...	...	...	...	...	...
1 Cr - 0.5 Mo	...	13 000[a]	4 500[a]	1 700[a]	...	...	...	...
1.25 Cr - 0.5 Mo	...	16 000[a]	7 000[a]	2 000[a]	700[a]	150[b]	...	...
2 Cr - 0.5 Mo	...	10 500[a]	6 400[a]	3 000[a]	1 100[a]	...	...	...
2 Cr - 0.5 Mo - 1.25 Si	23 000[a]	11 750[a]	4 400[a]	2 800[a]	...	...	...	...
2.25 Cr - 1 Mo	...	13 100[g]	6 380[g]	2 450[g]	...	...	...	...
	...	14 800[a]	8 200[a]	4 500[a]	1 500[a]	...	...	...
3 Cr - 0.5 Mo - 1.25 Si	...	11 250[a]	5 000[a]	3 400[a]	1 950[a]	...	270[a]	...
	...	...	4 000[e]	...	...	...	...	...
	...	...	2 100[e]	...	...	...	...	...
5 Cr - 0.5 Mo	...	14 500[a]	6 700[a]	3 000[a]	1 300[a]	...	105[a]	...
	...	...	2 500[e]	2 000[e]	...	...	...	...
5 Cr - 0.5 Mo - 1.5 Si	...	10 000[a]	5 400[a]	3 150[a]	1 850[a]	...	470[a]	...
	...	...	4 200[e]	2 000[e]	...	...	...	...
5 Cr - 0.5 Mo Ti	...	9 600[a]	3 500[a]	1 925[a]	1 225[a]	...	...	...
7 Cr - 0.5 Mo	...	...	...	3 100[g]	1 130[g]	...	...	...
	...	...	8 400[a]	3 600[a]	1 700[a]	...	250[a]	...
9 Cr - 1 Mo	...	...	11 800[a]	4 600[a]	1 600[a]	...	420[a]	...
18 Cr - 8 Ni	...	...	...	7 200[a]	3 700[a]	2 600[a]	1 700[a]	1 200[a]
	...	...	...	10 500[h]	3 500[h]	...	1 300[h]	...
	...	...	...	...	4 400[h]	...	...	...
	...	...	...	13 000[a]	6 200[a]	...	1 800[a]	...
18 Cr - 8 Ni Cb	...	...	16 000[a]	6 200[a]	2 800[a]	...	...	...
	...	...	30 500[a]	21 000[a]	11 500[a]	...	...	...
18 Cr - 8 Ni Mo	...	...	...	12 500[a]	8 900[a]	4 200[a]	1 600[a]	725[h]
25 Cr - 12 Ni	...	...	...	14 000[a]	6 800[a]	...	2 900[a]	1 000[a]
	...	...	...	10 000[a]	1 650[a]	...	820[a]	480[a]
25 Cr - 20 Ni	...	21 000[a]	16 000[a]	7 800[a]	4 400[a]	2 800[a]	1 600[a]	1 300[a]
	...	14 000[a]	6 400[a]	3 100[a]	960[a]	450[a]	280[a]	250[a]

[a] "Digest of Steels for High Temperature Service," Timken Roller Bearing Co., Steel and Tube Division (1946).
[b] "Résumé of High Temperature Investigations Conducted During 1945," The Timken Roller Bearing Co., Steel and Tube Division (1945).
[c] E. L. Robinson, "High Temperature Creep and Rupture Tests," *Proceedings*, Am. Soc. Testing Mats., Vol. 40, p. 811 (1940).
[d] S. H. Weaver, "The Effect of Carbide Spheroidization upon the Rupture Strength and Elongation of Carbon-Molybdenum Steel," *Proceedings*, Am. Soc. Testing Mats., Vol. 46, p. 856 (1946).
[e] R. H. Thielemann, "Some Effects of Composition and Heat Treatment on the High Temperature Rupture Properties of Ferrous Alloys," *Proceedings*, Am. Soc. Testing Mats., Vol. 40, p. 788 (1940).
[f] E. L. Robinson, "Some 1000 F. Steam Pipe Materials," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 70, p. 855 (1948).
[g] "Properties of Carbon and Seamless Alloy Steel Tubing for High Temperature - High Pressure Service," *Technical Bulletin No. 6E*, The Babcock & Wilcox Co. (1948).
[h] "Résumé of High Temperature Investigations Conducted During 1943 and 1944," The Timken Roller Bearing Co., Steel and Tube Division.

Pacific Area Papers

Continuing to keep the membership informed as to the availability of papers which were presented at the First Pacific Area Meeting of the Society last fall, there follows a table which summarizes the status of those papers which have been published or which will appear shortly. All of these papers' titles and their authors are listed in the 1949 *Proceedings* of the Society starting on p. 119. In the July, 1950, BULLETIN a table was published which described the availability of the papers not included in the present table.

RÉSUMÉ OF WEST COAST PAPERS PUBLICATION AVAILABILITY.

Title of Paper	Authorship	Publication Medium	Date Published
Symposium on Plasticity and Creep of Metals			
Experimental Exploration of Plastic Flow in Sheet Metals	L. R. Jackson and W. T. Lankford	Special Technical Publication *STP No. 107*	December, 1950
Forming Parameters and Criteria for Design and Production	William Schroeder		
Use of Creep Data in Design	H. C. Cross and L. R. Jackson		
Super Creep-Resistant Alloys	J. W. Freeman, D. N. Frey, E. E. Reynolds, and A. E. White		
Bituminous Paving Mixtures (to be combined with papers on Triaxial Shear presented at the 1950 Annual Meeting)			
Corps of Engineers' Method for Design and Control of Asphalt Paving Mixtures	Gayle McFadden and W. C. Ricketts	Special Technical Publication *STP No. 106*	January, 1951
History and Theory of Triaxial Testing and the Preparation of Realistic Test Specimens—A Report of the Triaxial Institute	V. A. Endersby		
Application of the Triaxial Test to Bituminous Mixtures—California Research Corporation Method	V. R. Smith		
Application oft he Triaxial Test to Bituminous Mixtures—Hveem Stabilometer Method	F. N. Hveem		
Session on Wood			
Studies of the Strength of Glued Laminated Wood Construction	A. L. Freas	ASTM BULLETIN	December, 1950
Physical and Mechanical Properties of Second-Growth Douglas Fir	J. B. Alexander	ASTM BULLETIN	October, 1950
Strength and Related Properties of Old-Growth Douglas Fir Infected with *Fomes pini*	J. R. Stillinger	ASTM BULLETIN	January, 1951
Mechanical Properties of Second-Growth Redwood and Comparison with Virgin Timber	Emanuel Fritz	ASTM BULLETIN	October, 1950
Predicting Durability of Exterior Plywood	N. S. Perkins	Printed by Forest Products Research Society	.....
Paint			
Laboratory Testing of Rain-Erosion Resistance of Aircraft Finishes	J. K. Grace and G. C. Frey	ASTM BULLETIN	September, 1950
Evaporation Rate of Hydrocarbons and Their Mixtures	L. S. Galstaun	ASTM BULLETIN	December, 1950

1951 Annual Meeting Symposiums

DEFINITE information has now been received regarding some of the symposiums to be presented at the 1951 Annual Meeting which it is expected will be held in Atlantic City the week of June 18–22.

Committee E-11 on Quality Control of Materials is sponsoring a session on Bulk Sampling which will consist of five papers covering various materials such as coal, wool, food products, and wire. They will cover also the mechanical essentials for statistical sampling.

In the proposed Symposium on Acoustical Materials sponsored by Committee C-20, it is planned to cover the history of the acoustical materials industry pointing out the need for standardization in testing procedures, basic physical properties, measurement of sound absorption, and application, maintenance and combustibility of acoustical materials.

Committee C-19 is arranging for an interesting group of papers to be presented covering developments in structural sandwich building panels using inorganic cores, fabrication techniques, construction in the elastic range, testing and strength of construction, aluminum and paper honeycomb as a core for structural sandwich construction, radome, and other electrical sandwiches.

Papers on Consolidation Testing of Soils, under the sponsorship of Committee D-18, will cover tests with peat, aid in the interpretation and application to highway foundations, and application of controlled test methods.

Committee D-18 is also sponsoring a Symposium on Surface and Subsurface Reconnaissance which will cover papers on engineering implications of geological reconnaissance in the plains area, interpreting geological maps, and application of aerial photographs to preliminary engineering soil surveys.

Under the joint sponsorship of Committee C-1 on Cement and D-2 on Petroleum Products a Symposium on Flame Photometry is in prospect. It will consist of two sessions each containing four to five papers. At one of these sessions Committee D-19 will sponsor a paper dealing with methods of flame photometry that are applied to industrial water. Papers covering use of flame photometry in the petroleum field will cover such subjects as calcium in lubricating oil, effect of organic solvents, and methods of eliminating interferences. In the cement field, papers will deal with water-soluble alkalies in portland cements, base exchanges in pozzolans, optimum gypsum content of cement, premature stiffening in cement, and the discussion of the Perkin-Elmer and Beckman instruments used in the determination of alkalies in portland cement.

A considerable number of offers are already in hand covering individual papers for presentation at the Annual Meeting. Additional offers will be received up to January 16.

Offers of Papers for 1951

THE Administrative Committee on Papers and Publications will meet early in February to consider the papers to be published by the Society in 1951 and to develop the program for the 1951 Annual Meeting to be held in Atlantic City, N. J., June 18–22. All those who have in mind offering papers for presentation at the Annual Meeting and publication by the Society should send these offers to Society Headquarters *no later than January 16*. All offers should be accompanied by a Summary which should make clear the intended scope of the paper and indicate features that, in the opinion of the author, will justify its inclusion in the Annual Meeting program and publication by the Society. Suitable blanks to be used in transmitting the desired information will be sent promptly on request.

Latest Standards Committee Approvals; New High-Type-Bond Reinforcement Bar

IN RECENT weeks the Administrative Committee on Standards has approved four recommendations from Committee A-1 on Steel for the revision and reversion to tentative of four specifications described below. The Standards Committee has also approved revision and reversion to tentative, on the recommendation of Committee E-8 on Nomenclature and Definitions, of Definitions Relating to Heat Treatment of Metals (E-44).

Among the steel revisions, a series of bar number designations to replace the former size designations and explanatory notes clarifying the size equivalent of the bar numbers have been added to the standard specifications covering minimum recommendations for the deformations of deformed steel bars for concrete reinforcement (A 305). This action will bring A 305 in conformity with Simplified Practices Recommendation R 26 and with practices unanimously recommended by producer interests.

Revisions in standard specification A 15 – 39 covering steel bars for concrete reinforcement, including the incorporation of the present tentative revision into the body of the specification, have been made. The work of various research groups in developing a new standard high-type bond bar which has long been the search of designers is now in effect as a result of this action. The revision has had the enthusiastic endorsement of large engineering groups representing both consumers and producers. Also, to clarify the interrelation of Specification A 15 and A 305, the scope clause of A 15 has been broadened to define a deformed bar as that conforming to the requirements of Specification A 305; to further clarify the new numbered designations of bars, a table of bar designations and the corresponding dimensional values of those bars has been introduced in accordance with Simplified Practices Recommendation R 26.

Standard specifications A 16 covering rail steel bars and A 160 covering axle steel bars were revised in a manner similar to A 15. With the revisions, all four of the standards were reverted to a tentative status.

The Standard Definitions of Terms Relating to Heat Treatment of Metals (E 44) were revised based upon agreements reached in the Joint Committee on Definitions of Terms Relating to Heat Treatment, whose membership comprises representatives from ASTM, Society of Automotive Engrs., American Society of Metals, and American Foundryman's Society. This revision will bring the old definitions in ASTM Standard E 44 into agreement with the present Joint Committee definitions. The work on the glossary had been under way in the joint committee for several years.

The five standards which have been revised and reverted to tentative are listed in the accompaning table.

Approvals by the ASTM Administrative Committee on Standards, November, 1950

Revision of Standard and Reversion to Tentative

Specifications for:

Minimum Requirements for the Deformations of Deformed Steel Bars for Concrete Reinforcement (A 305–49)
Steel Bars for Concrete Reinforcement (A 15 – 39)
Rail Steel Bars Concrete Reinforcement (A 16 – 35)
Axle Steel Bars Concrete Reinforcement (A 160 – 39)

Recommended Practice for:

Terms Relating to Heat Treatment of Metals (E 44 – 43)

1951 and 1952 Meetings of ASTM

1951

Spring Meeting and Committee Week
Cincinnati, Ohio
March 5 to 9, inclusive

Annual Meeting
Atlantic City, N. J.
June 18 to 22, inclusive

1952

Spring Meeting and Committee Week
Cleveland, Ohio
March 3 to 7, inclusive
(probably)

Annual Meeting
New York, N. Y.
June 23 to 27, inclusive
The biennial Apparatus and Photographic Exhibits will be held in conjunction with this Annual Meeting.

First Building Research Conference—London, 1951

A COMPREHENSIVE congress on building research is to be held in London, England, from September 11 to 20, 1951, and will be the first of its kind ever to be held. It will review the progress made in research in relation to architecture, building, and the associated branches of civil engineering since the end of the recent World War.

The Congress is sponsored by the British professional institutions and learned societies interested in building science, and by government departments, with the support of repesentative industrial federations in Great Britain. The Department of Scientific and Industrial Research is providing the central organization for the Conference. Papers are being invited from research workers in many countries on a wide range of topics, and arrangements are being made to welcome to the Congress a large number of visitors from overseas.

The effect of summer and winter conditions on the heating and cooling of buildings; the lighting of buildings; problems of special types of buildings, particularly schools, hospitals, and factories; the acoustics of auditoriums and broadcasting studios—these are some of the topics to be covered in an architectural way.

Mechanization of building operations; prefabrication; steelwork design; concrete design; soil mechanics and the design of foundations—these will reflect the civil engineering aspects of building science.

Weathering and durability of building materials in temperate and extreme climates; lightweight concrete; quality control and accelerated curing of concrete; development in manufacture and the structural use of burnt clay products; stone for housing and developments in quarry mechanizations; gypsum products, limes, pointing—these will point up the materials engineering fields.

Those interested should notify the Organizing Secretary, Building Research Congress 1951, Building Research Station, Bucknalls Lane, Garston, Watford, Herts, England.

ELECTROLYTIC tinplate, which has largely supplanted the hot dip method of manufacture in the postwar era, conserves over 50 per cent of the nation's tin supply, according to the American Electroplaters' Society.

ASTM Bulletin

DECEMBER 1950

NO. 170

NINETEEN-SIXTEEN
RACE STREET
PHILADELPHIA 3, PENNA.

Sustaining Membership Has Numerous Advantages

Companies and the Society Benefit

IN ESTABLISHING in the 1930's the class of Sustaining Membership, so that leading companies could give financial support to ASTM work to a greater degree than was represented by the individual and company classes of membership, the Board of Directors also provided a number of distinct advantages for this class. From its inception this class of membership, the dues for which are now $150 a year, has met with very warm reception on the part of many leading companies, and at the present time there are about 215 Sustaining Members. In the near future invitations are to go out to other organizations, many of which are quite active in the Society, to consider this class of membership. Most of the present Sustaining Members were at one time company members and transferred from that class to the sustaining group.

Many Publications Furnished:

While the Sustaining Class of Membership is intended to give added financial support to the Society's operations, the policy nevertheless has been to furnish additional publications to Sustaining Members over and above those furnished to regular individual and company members which in itself is considered to be rather liberal. Here are some of the publication privileges granted Sustaining Members:

Book of Standards

The annual charges for extra Parts of the Book are waived, and when requested an extra copy of Parts of the Book is furnished without charge.

Symposiums and Special Compilations

The Sustaining Member has the privilege of requesting a copy of any of these special books which are normally furnished only on sale at special prices to members.

Regular Publications

The *Proceedings*, Year Book, and Index to Standards are regularly furnished, and additional copies of the ASTM BULLETIN may be secured regularly.

In addition to the publication advantages, Sustaining Members, of course, have all the other privileges of the company class including the one of designating different technically qualified individuals to serve on diverse committees to which the company may be elected.

Although the annual dues of $150 for Sustaining Membership are not excessive, nevertheless in the aggregate these dues represent a not inconsiderable contribution to the Society's income, and the Board of Directors is most anxious that other organizations which are benefiting from the ASTM standardization and research work, give consideration where feasible to this class of membership.

Further information concerning Sustaining Members will be gladly furnished on request.

Purchasing Agents and ASTM

IT IS a sure bet that today, out in American Industry Inc., G. O. Bye, Purchasing Agent, is studying intently some ASTM specification. The standard could be A 179 for Seamless Steel Heat-Exchanger and Condenser Tubes.

Probably Mr. Bye is studying that specification as Mr. D. Zine, Chief Project Engineer, looks over his shoulder. You see both men are part of a team whose job it is to develop, design, and build "Process X" which will be the best due, in part at least, to the fact that both Mr. Bye and Mr. Zine know that to specify ASTM for condenser tubes is to *guarantee* an acceptable product—to insure uniformity, dependability, and performance.

This is not a hypothetical scene taking place—the actual standard may not be A 179, but one or more of the over seventeen hundred standards which have been put together in ASTM, by producers and consumers jointly, after months, or years, of careful work. Mr. Bye might be putting his "OK" on structural steel to be purchased—or melamine plastic—or air-entraining cement. But you can rest assured that he *is* studying *some* ASTM standard!

Schedule of ASTM Meetings

DATE	GROUP	PLACE
December 6	Committee D-21 on Wax Polishes and Related Material—Executive	New York, N. Y.
December 7–8	Committee C-13 on Concrete Pipe	St. Louis, Mo.
January 15–16	Board of Directors	Philadelphia, Pa.
January 16	Philadelphia District	Philadelphia, Pa.
January 30–31	Committee B-5 on Copper and Copper Alloys	Philadelphia, Pa.
February 4–9	Committee D-2 on Petroleum	Washington, D. C.
February 5–7	Committee A-1 on Steel	Cleveland, Ohio
February 20	Philadelphia District	Philadelphia, Pa.
February 26–28	Committee D-1 on Paint, Varnish, Lacquer, and Related Products	Washington, D. C.
February 27	Committee E-12 on Appearance	Washington, D. C.
March 5–9	**SPRING MEETING AND COMMITTEE WEEK**	**Cincinnati, Ohio**
March 14–16	Committee D-13 on Textile Materials	New York, N. Y.
March 22	Philadelphia District	Philadelphia, Pa.
April	Committee D-14 on Adhesives	Washington, D. C.
April 16–17	Committee D-10 on Shipping Containers	Atlantic City, N. J.
April 21	Committee C-21 on Ceramic Whiteware	Chicago, Ill.
April 25–26	Committee D-21 on Wax Polishes and Related Materials	Chicago, Ill.
June 18–22	**ANNUAL MEETING**	**Atlantic City, N. J.**

A continuous stream of inquiries is received at Headquarters from purchasing agents requesting information on our specifications and tests. These are aside from the hundreds of orders which come in from them to purchase our publications for their respective companies. Also on permanent file at Headquarters are hundreds of requests from purchasing agents to receive regularly the annual Index to ASTM Standards. (This valuable publication is sent gladly to *any* purchasing agent, on request, and provides him with a convenient means of determining whether there are any ASTM standards covering a particular material or subject.)

The tie between purchasing agents and ASTM is emphasized by the fact that since 1918 the National Association of Purchasing Agents (N.A.P.A.) has been a member of the Society. Its officers have rendered valuable cooperation—Mr. George A. Renard, Secretary-Treasurer of N.A.P.A. has on many occasions aided our Society's efforts. Reviews of ASTM's publications are frequently carried in the N.A.P.A. *Bulletin*. Also, organs of local purchasing agents' associations publicize ASTM's work.

Realizing that each purchasing agent is a potentially strong source of benefit to ASTM, each year the Society sends to the N.A.P.A. executive group and the heads of its various sections, complimentary copies of the Index to Standards. Our members in the various companies will vouch for the Society's readiness to assist in a purchasing agent's problems at any time. Furthermore, if any of these members would like to see a copy of our Index placed in the hands of his associate—the purchasing agent—Headquarters will be glad to place the name of the purchasing agent on our mailing list for the Index.

Award of Merit Committee

WITH the acceptance of Past-President Dean Harvey and Louis J. Trostel, the personnel of the 1951 Award of Merit Committee is completed. These two men will serve with hold-over members, L. H. Winkler (as Chairman) and Carlton H. Rose, and Past-President Richard L. Templin representing the current Board of Directors on this committee. Some details of the operations of the Award of Merit Committee were given in the October, 1950 BULLETIN, and page 575 of the current ASTM Year Book gives the rules governing the Award of Merit in which the ASTM technical committees have an important part.

ASTM DISTRICT ACTIVITIES

Yardsticks Needed for Air and Stream Pollution Programs

Leading Technologists Speak at Ohio Valley District Meeting

SPEAKING at the first formal meeting of the Ohio Valley District since its organization, L. F. Warrick, Chief of the Technical Services Branch, Division of Water Pollution, U. S. Public Health Service, Washington, D. C., stressed the importance of teamwork between the Federal Government and the states, industry, and technical organizations in establishing yardsticks for measuring stream pollution. He said the problem cannot be fully appreciated until a satisfactory measurement of pollution is made.

H. G. Dyktor, Commissioner, Division of Air Pollution Control, City of Cleveland, stated that the problem of air pollution is a conflict between residents of a city and industries of a city and that city government must reconcile their differences.

The program had been opened with a tour of Battelle Memorial Institute arranged by H. P. Munger. Following the tour, over 100 members and friends of ASTM attended a dinner where Dean MacQuigg, Ohio State University, presided. R. E. Hess, Technical Secretary of ASTM, discussed the purpose of the American Society for Testing Materials. He emphasized that ASTM is an effective instrument for bringing together representatives of consuming and producing interests so that specifications and testing methods on materials of engineering can be formulated which are agreeable to both. Also, ASTM is identified as the hard-working members themselves, working for order from confusion.

When ASTM was young, with comparatively few members, it was relatively easy for many in the Society to meet each other personally and to be somewhat familiar with one another's problems and work. But, as technology branched and expanded, as the Society grew, as the number of members increased, and as the number and size of the Society's meetings became larger, this community aspect of the Society started to disappear. To help offset the tendency, ASTM Districts were formed. One of the chief functions of the District meetings today is that they afford an opportunity for members and friends in many industries to hold meetings of a general character and help maintain this warm personal note among the various individuals and groups concerned with materials within a given geographic locality.

The technical session, attended by over 200, was opened by Chairman J. C. Harris who introduced the speakers for the evening and the members of the panels for discussing air and water pollution. Leading men in the field serving on the air pollution panel were H. C. Ballman, H. P. Munger, C. A. Gosline, and H. B. Lammers. Authorities serving on the water pollution panel were L. D. Betz, F. H. Waring, C. V. Youngquist, H. D. Lyons, T. F. Reed, and C. A. Snavely.

Mr. Dyktor said air pollution legislation should be of a control nature. He also pointed out that the Federal Govern-

L. F. Warrick

H. G. Dyktor

ASTM meeting, Hughes Hall, Ohio State University. Left to right: Jay C. Harris, H. G. Dyktor, Louis F. Warrick, R. E. Hess.

ment has no part in air pollution legislation except in the granting of moneys for research in pollution abatement. He believed that the air pollution problem is really *two* problems: One, smoke abatement, should be the easiest to solve since the results of work already done in the last forty or fifty years can be applied to help solve it. However, abatement of the other nuisance, chemical fumes, may be far more difficult. He emphasized that cooperation of the people and industry around a conference table is the modern way of handling pollution problems. Sincere attempts in pollution abatement foster good public relations for industry, he pointed out. Part of the policy of any air pollution group must be to educate people that pollution can only be reduced to a tolerable level and that they must appreciate that cities *need* industries if they are to maintain their commercial status.

L. F. Warrick, in his talk, spoke of the first real approach to the problem of water pollution. He cited the fact that the Ohio River Compact involves eight states and that its primary purpose is to reduce the concentration of stream pollution to a point which will allow the streams to conform to the standards of downstream pollution. He stated that, among the stream pollution functions of the Public Health Service, research, technical aid to cities and industries, and the education of the general public are the most important. Water pollution calls for Federal and state teamwork since stream pollution originating in one state may influence the water in several states downstream. He said that industries must solve the problem of stream pollution and that good housekeeping is necessary in industrial plants to prevent the disposal of unnecessary wastes. Closed systems to reclaim pollution components are desirable. As an example of this last, he pointed out that the paper industry is using "savealls." He also mentioned that radioactive pollution will be an important consideration in this atomic age. It is a problem about which a number of universities and the Atomic Energy Commission are seriously concerned even now. A panel discussion on both air and water pollution followed Mr. Warrick's talk.

Considerable interest was shown in a display of ASTM Publications at the recent Ohio Valley District Meeting, Columbus, October 13, 1950.

ASTM dinner, Baker Hall, Ohio State University. Left to right: J. C. Pitzer, E. W. Campion, John H. Calbeck, Louis F. Warrick, Jay C. Harris, H. G. Dyktor, R. E. Hess, C. E. MacQuigg.

Messrs. MacQuigg and Munger, acting for the Ohio Valley District, should have much gratification at the outcome of the successful meeting which resulted largely from their efforts, in collaboration with the District Officers.

Effects of Atomic Bombing

THE meeting on "Effects of Atomic Bombing" sponsored by the ASTM New York District, on Friday, October 6, at the Engineering Societies Building was a most interesting one. About 150 members and their friends attended the meeting, with a goodly sprinkling of ladies present. District Chairman H. C. R. Carlson presided introducing several men in the audience. ASTM Assistant Secretary R. J. Painter mentioned that the 1952 Annual Meeting of the Society in New York would be a special one in connection with the celebration of the Society's Fiftieth Anniversary. This is to be held at the Hotel Statler during the week of June 23 to 27, 1952. He also mentioned the Society had honored several men from the District either as honorary members or as recipients of the new ASTM Award of Merit. Dr. T. S. Taylor, one of the first Award of Merit recipients, was introduced.

There was much interest in the meeting due to the speaker, Edward J. Kehoe, Chief, Fire and Accident Branch, New York Operations Office, U. S. Atomic Energy Commission; and also the Technical Chairman, Mr. Robert L. Krummel, Aide to Director-Civil Defense, City of New York, on loan to the city from Consolidated Edison Co. Both men were good speakers and have had much experience in the work they are doing.

Mr. Krummel outlined some of the basic considerations of New York City defense, referring to similar problems which had been studied, for example, in Germany.

Since there appears on p. 16 an abstract of the paper by Mr. Kehoe, no further comments seem necessary, although one would gather the definite impression that the most serious consequences of an atomic explosion are not the radiation effects but those associated with the explosion itself. He stressed this on two or three occasions.

As part of his talk he showed a film which included some of the better motion pictures of the explosion at Bikini and the aftermath of the bombs dropped in Hiroshima and Nagasaki.

Southern California District Officers

SHORTLY after his election as Chairman of the Southern California District, H. W. Jewell, formerly of Pacific Clay Products, changed his affiliations to the National Sewer Pipe Co. in Toronto, Canada, and hence resigned the Chairmanship. The District Council, which is empowered to fill vacancies, has therefore elected as Chairman, C. M. Wakeman, Los Angeles Harbor Department Testing Laboratory, Wilmington, Calif. Mr. Wakeman, a member of the Council for many years, was Vice-Chairman of the District. To fill the vacancy of Vice-Chairman, the Council has appointed Dr. E. F. Bergman, C. F. Braun & Co., Alhambra, Calif. Myron B. Niesley, California Testing Laboratories, Inc., Los Angeles, is the District Secretary. The complete personnel of the Council is given on page 9 of the new Year Book.

Members in Alabama and in Georgia Hold Meetings for First Time

IN CONNECTION with a recent trip of Assistant Secretary Painter to the Southeast, a number of members and committee members of the Society in Alabama and in Georgia had luncheon meetings. The first meeting was in Birmingham on October 19, the Georgia members convening in Atlanta on the twentieth. This was the first time that meetings of our members in these areas had been held, and the representative attendance at each luncheon indicated the interest of our members in the Society.

In Birmingham, J. R. Trimble, Tennessee Coal, Iron and Railroad Co., a member of the Board of Directors, handled the rearangements; and in Atlanta a committee on arrangements consisting of Messrs. W. H. Mills, C. W. Dietterich, and R. G. Lose was in charge. Following an illustrated talk on Society matters, there was a brief period of discussion at each meeting.

These meetings gave our members in these states an opportunity to become better acquainted and to review some of the plans and problems in the Society's operations.

At the Birmingham luncheon, it was a pleasure to have the presence of several ladies, including Miss Josephine F. Eddy, Head, Textile and Clothing Dept., Alabama College, and Miss Henrietta M. Thompson, Head, Department of Clothing and Textiles, University of Alabama, with some associates. Also, a former very active ASTM member and officer, many years with the Tennessee Coal, Iron and Railroad Co., Oscar U. Cook, was present, as was Dr. J. T. MacKenzie, American Cast Iron Pipe Co., another past Director.

Within the year, members of the Society in such scattered industrial centers as the Twin Cities (Minneapolis and St. Paul), Portland, Dallas, Houston, New Orleans, Birmingham, and Atlanta have met for the first time in connection with visits by members of the Staff. There is no thought at the present of organizing Districts in these areas, but it has been found desirable from various points of view to have our members meet one another. Next spring, President Markwardt and Executive Secretary Warwick plan to visit certain western states; further meetings of our members are being planned. Members in the industrial centers concerned will be posted directly in more detail.

President at Pittsburgh District Smoker

ABOUT 60 members of the Pittsburgh District were at the smoker at the University Club on Monday, November 6, and greeted President L. J. Markwardt and Executive Secretary C. L. Warwick. The meeting was specifically arranged so that these two Society Officers could get to meet and chat directly with our Pittsburgh people.

While the affair had been arranged by the Pittsburgh District Officers, M. D. Baker, Chairman; F. T. Mavis, Vice-Chairman; and H. H. Hebley, Secretary, as strictly an informal affair, both the President and Executive Secretary did speak briefly.

There is little enough opportunity for our members, themselves always extremely busy with their own business and professional activities, to greet the Society Officers who are also under a heavy schedule; and the Administrative Committee on District Activities has welcomed the interest of the Pittsburgh District and others in sponsoring these informal smokers. But the turnout at Pittsburgh was very gratifying. Refreshments were served. Advice from some of those present indicated that the affair was thoroughly enjoyable.

Calendar of Society Events

"Long" and "short" calenders will appear in alternate BULLETINS. The "short" calendar notes meetings in the few immediate weeks ahead—the "long" calendar for months ahead.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE—117th Meeting, December 26–31, Public Auditorium and Downtown Hotels, Cleveland, Ohio.

SOCIETY OF AUTOMOTIVE ENGINEERS—Annual Meeting & Engineering Display, January 8–12, 1951, Book-Cadillac, Detroit, Mich.

SOCIETY OF PLASTICS ENGINEERS, INC.—7th Annual National Technical Conference, January 18–20, 1951, Hotel Statler, New York, N. Y.

NATIONAL CONCRETE MASONRY ASSOCIATION—Annual Meeting & Exhibit, January 22–25, 1951, Cleveland Auditorium, Cleveland, Ohio.

Atomic Bomb Effects

Extended Abstract of Talk by Edward J. Kehoe

When the atomic bomb bursts at Hiroshima and Nagasaki signaled the end of the recent World War, few recognized immediately the possibility that such weapons might eventually be used against the United States. This possibility must now be faced. Good fire fighting strategy always calls for a clear size-up of how serious the situation is upon arrival at a fire. It is important that we make the same size-up of the atomic bomb burst and evaluate it correctly; it certainly will not be reasonable to ignore this threat or to collapse into impotence through fear. From an intelligent interpretation of what happened in previous fire raids and atomic explosions, it is possible to determine what might possibly happ ı to a particular American city and to lay plans accordingly.

To begin with, it is important to emphasize precisely what the function of the Atomic Energy Commission is relative to civil defense planning. As Mr. Gordon E. Dean, Chairman of the AEC, explained before the Joint Congressional Committee on Atomic Energy in March of this year:

"...In an exchange of correspondence in July, 1949, it was agreed by us and by the National Security Resources Board that 'the Commission's role in civil defense planning will be in large measure one of supplying information to other agencies with primary responsibility for civil defense planning'...."

Jointly with the Department of Defense, we have prepared pertinent publications for the NSRB for distribution to state and Government authorities. These publications are "Medical Aspects of Atomic Weapons," "Damage from Atomic Explosion and Design of Protective Structures," and "The Effects of Atomic Weapons" which was released this month; all of these publications may be obtained from the Government Printing Office.

In addition to supplying this technical information, the AEC at the request of NSRB has already completed courses in radiation monitoring and in the handling of radiation casualties for technically qualified representatives designated by the state governors. The thought was that these trained representatives might carry on the training within their respective states after completing our courses.

In considering the atomic attacks on Hiroshima and Nagasaki, it is extremely important to understand that in both of those cases the effects were almost entirely those of a huge explosion and that compared to those effects usually associated with a terrific explosion, the effects of the radiation were only minor. The two Japanese attacks killed over 106,000 people. *Only 5 to 15 per cent of the deaths were directly attributable to radiation;* the vast majority of deaths were caused by the usual high explosive effects, such as concussion, falling walls, shattered glass, burns, and other causes. All of those killed by radiation received their lethal dose within seconds after the bombs were detonated, and in both cities *there were no cases of damage to human beings from residual activity.*

Incidentally, while we are primarily concerned with atomic bomb effects in this discussion, it is important to realize that the fire raids on Hamburg killed more people than the atomic bomb burst at Nagasaki. The damage done at Hamburg was equal to that from two atomic bombs.

I am of the opinion that the radiation aspect of the Japanese blasts has been overemphasized in the minds of our people.

Considering radiation itself, to simply say that something is "radioactive" does not mean that it is necessarily lethal or that it must be feared; to say that something is "radioactively contaminated" is not being sufficiently definitive (unless the standard is known) and does not necessarily mean that we cannot have any contact with it. As a matter of fact, all of us have been exposed to radiation for a long time. Even before man existed the radiation of cosmic rays was striking down upon the earth from the skies; radioactive elements like radium in the earth itself give off radiation. Many of the most popular mineral waters drunk by people in the United States are naturally radioactive. Your face gets more radiation, when you get your teeth X-rayed, than you would receive over a period of a year working in one of the plants operated for the AEC.

There is one phase of the subject of radiation which merits attention. You have heard of the extremely careful health program which is operated by the AEC and its contractors. Perhaps you have read of the elaborate precautions that were taken when a small amount of radioactive material was accidentally released at a military training center and was tracked around on the shoes of the students. It is necessary that we understand the difference between the radiation dose which may be accepted under wartime conditions as compared to peacetime conditions. The tolerance level of radiation absorption used for the employee in our plants is extremely low because the man may be exposed day after day, year after year for his entire working life. An individual who is exposed to radiation only on rare occasions, as, for example, in the emergency condition of fire fighting can take as many as 500 times this low tolerance without any permanent ill effects. In a group of firemen who might be called upon to combat the conflagration resulting from an atomic bomb burst, a small portion might possibly receive ill effects, probably of a temporary nature, from radiation; however, this will actually be much less of a risk than the other risks which a fire fighter takes at such times such as danger from falling walls, bursting hose lines, flying glass, and traffic accidents.

Effects of Burst Location:

The three general ways in which an atomic bomb might be detonated are underwater, underground, or high in the air. The high air burst is probably the most effective use of a bomb against a city since it gives maximum destructive effect over the widest area. This is the type of burst used at Hiroshima and Nagasaki. It will produce the most casualties, the greatest damage and the largest fires, but it will leave no radiation hazard. Those who are killed or injured by radiation from this type of burst will receive their injury in the seconds following the instant of the bomb burst. The radiation can kill all of the people exposed in the open within 2100 ft. of the burst and half of those exposed in the open at 4200 ft. As a practical consideration, most of those in the open in the area cited will be killed by direct concussion and such blast effects as falling walls, flying debris, shattered glass, and so forth. Any type of substantial shelter, especially one below ground, even a slit trench, will provide shielding from much of the radiation and blast, and thus will reduce the casualties. For practical purposes, the radiation problem is over in seconds in this type of burst. It is important to know that the bodies of those killed by the highest doses of radiation are not at all radioactive and can be safely handled.

When the atomic bombs were detonated over Hiroshima and Nagasaki, neither of the cities was in a state of air raid alert. They had been alerted but because only one plane flew over, it was assumed to be on reconnaissance mission and the all-clear was sounded. Some few people who remained in air raid shelters close to the point directly under the burst (zero point) escaped unharmed. This emphasizes the high value of air raid warning and shelter precautions.

When the high-level air burst occurs, there is a terrific burst of heat which in Japan caused flash charring and ignition of materials up to two miles from the zero point and caused large numbers of personal injuries. It is this radiant energy, which, like all heat, was reflected by light materials and absorbed by dark materials, which was responsible for the patterns burned on buildings and on people. This radiant heat was probably not responsible for any large proportion of the fires which broke out. While the radiant heat does attain a very high temperature and has a scorching effect, it generally does not last long enough to bring combustible materials to their ignition temperature. The fires which broke out were mainly secondary fires due to the blast damage which caused complete destruction in an area about one half mile from the zero point and severe damage to an area somewhat over 1 mile from the zero point, with decreasing damage further out to 8 miles. This tremendous blast disrupted stoves, gas lines, electric lights, and other sources of fires, generally throughout an area a mile from zero point. Many fires started and quickly merged into one. At Hiroshima a fire storm developed and included a strong inward draft toward the fire from all points of the compass at ground level. This helped to limit the area burned but virtually everything combustible within this area was destroyed. At Hiroshima, 70 per cent of the fire fighting equipment was destroyed or rendered unserviceable

and 80 per cent of the personnel of the fire department were killed or injured severely. At Nagasaki the fire pattern was different. No fire storm developed and the fire was subject simply to the normal winds; the long narrow valley of Nagasaki tended to confine the fire, whereas Hiroshima was a relatively flat city. This fire storm phenomenon is by no means confined to atomic attacks. For example, a fire storm developed at the City of Hamburg, Germany, during an incendiary attack.

In the Japanese cities, with a few exceptions, where water mains passed through filled ground, there was practically no damage to the underground water distribution system. Water supplies already inadequate by our standards were depleted by the loss of water from broken building service connections. It seems possible, therefore, that high-pressure fire service systems from which no building connections are made would very likely be in service after such a blast. Above-surface hydrants in the blast area would suffer severe damage, but modern fire hydrants are so constructed that the destruction of the hydrant does not cause any loss of water.

The fact that in the Japanese cities, thousands of separate fires merged quicky into a general conflagration cannot be applied blindly to American cities without individual study. Whether or not a conflagration occurs after an atomic attack will be the result of many factors, such as weather, types of construction, natural or provided fire breaks, pre-planning, and whether sufficient warning is received. Probably one of the greatest of contributing factors to the Japanese fires was the existence of thousands of individual cooking fires in the wooden homes. However, the conflagration possibility cannot be dismissed entirely and such planning is still necessary; it will pay big dividends in the event of a large-scale disaster from any cause, peace or war.

The next type of detonation is the underwater burst. For example, consider an underwater burst in the normal shallow harbor. There would be a shock wave underwater which would destroy and damage ships within about 3000 ft. of the zero point. It is not believed, however, that piers and breakwaters would be seriously affected by the underwater shock wave. There would also be an air shock wave equivalent to that caused by the explosion of 4000 tons of TNT; while very powerful, this shock wave would be very much less than the 20,000-ton TNT equivalent involved in the air burst. The air shock wave would cause complete destruction or severe damage up to a little over one half mile from the zero point and partial damage would extend to over a mile. Thus, if the bomb were detonated underwater, one mile from shore, the structural damage would not be serious from the air shock wave. From an explosion in shallow water, waves 10 to 20 ft. in height or higher might be expected, and these would do severe damage to facilities on and close to the water's edge. Depending on how much damage is done on shore by the blast wave, there may be no fires or moderate fires. The fire problem should not be too severe, however, since the fire can move in only one direction (inland) and damage to fire department facilities, water supply, etc., should be much less than in the air burst. The extent to which radioactive materials would be showered on the land would depend upon the direction and strength of the wind, but, generally speaking, the radiation hazard around the fringes of the damaged area where necessary fire fighting would take place would not be so severe as to prevent fire-fighting operations. It might be necessary, however, to rotate the personnel occupying advance positions to reduce the time during which they are exposed to radiation.

A burst underground would probably produce effects similar to a strong earthquake across an area possibly 3000 to 6000-ft. in diameter. Damage to subsurface utilities, water supply, etc., would be severe and fire might or might not result as it has from earthquakes in the past. The radiation hazard would be high in the area close to the bomb burst and, to some extent, in a downwind direction due to airborne particles. There would be no tremendous air blast effect, however, and the number and types of casualties would be similar to those suffered in an earthquake. Fire-fighting effort in the highly radioactive area would probably be extremely limited because of the lack of water. The blast effects of a burst just above the ground would be similar to those of high level burst but much more limited in area. Damage to underground installations would be confined to a limited area directly underneath the burst. The residual radioactivity would be similar to that encountered after an underground burst.

All of the figures used in this talk are necessarily approximate. There are a number of conditions which will govern the actual damage done by an atomic bomb, beginning with the efficiency of the bomb itself and including such items as type of burst, natural and man-made physical conditions in the target area, the weather, our state of preparedness with respect to long-range planning, education of the population, and the amount of warning of an impending attack provided.

It can be seen from a review of the facts that the air burst is the most devastating type of bomb burst on a city from the viewpoint of physical damage. In such an attack, the fire-fighting problem would be extremely severe, but its major factors are those which would have to be coped with in a conflagration following any tremendous explosion; the hazard of radiation to those who survive the initial blast will be relatively minor. The physical damage at Hiroshima was equivalent to that by 325 tons of high explosives *and* that by 1000 tons of incendiaries distributed over the city.

It is possible to draw some ideas on fire defenses from the facts we have discussed. Consideration should be given to transferring some units of municipal fire apparatus, after careful study, from the high-value districts of a city to the outskirts. The manpower on duty in the high-value district could remain the same, thus enabling the fire chief to make full use of the capacity of the remaining apparatus in fighting peacetime fires. In most large cities, the shortage of manpower is generally the problem facing the fire chief rather than an insufficiency of pumping capacity. Off-duty personnel will generally be in residential districts, and in the event of atomic bomb attacks could report to the outlying fire stations to man the reserve apparatus. We must anticipate that fire-fighting units in the middle of the target area will suffer severe casualties, but these may be reduced by even so simple a procedure as going to the cellar when an atomic bomb attack impends; this of course necessitates a warning.

Even for peacetime service, our use of radio communications should logically be expanded to the point where communication to each unit is completely independent of local power and land wire service. This indicates the fullest utilization of radio-equipped apparatus and possibly a complete self-contained mobile transmitting headquarters normally stored in the outskirts of the city. Incidentally, radiation does not affect radio communication. Remember that in the Japanese attacks, telephone poles were snapped off at ground level carrying the wires down with them. Overhead utilities were heavily damaged at distances up to 10,000 ft. Underground electrical conduits were little affected. Switch gear and transformers were not damaged directly by blast but by secondary effects, such as collapse of a structure or by debris.

The atomic bomb is a terrific weapon, but its effects are by no means infinite. Many have probably read in a recent issue of *Colliers* an article entitled "Hiroshima, U.S.A." which described a hypothetical bombing of New York City. In it, the author made the supposition that the bomb killed 180,000 people. How many persons realized in reading the article that 180,000 deaths would have meant that *41* New Yorkers out of every *42* would have survived?

Nuclear Data

For nuclear physicists and engineers, radiochemists, biophysicists, and other workers in the field of nuclear physics tables are now available of Nuclear Data. These tables are to be followed by supplements of new material at six-month intervals. The initial volume of the tables, together with the supplements, will present a comprehensive collection of experimental values of half-lives, radiation energies, relative abundance of isotopes, nuclear moments, and cross-sections. Decay schemes and level diagrams, over 125 of which are included in the tables now ready, are to be provided wherever possible. 310 pages. Circular 499, Nuclear Data, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C.

ASTM TECHNICAL COMMITTEE NOTES

Cement and Concrete Committees Active—Fall Meetings at Skokie, Ill.

AN EXCELLENT opportunity was provided the members of Committees C-1 on Cement and C-9 on Concrete and Concrete Aggregates to visit the new laboratories of the Portland Cement Assn. in Skokie, Ill., on October 9 and 10. The laboratories, containing the latest in testing equipment and facilities, is undoubtedly one of the most modern and best in the field of cement and concrete today and reflects the importance that the cement industry places on research and testing. As guests of the PCA the two committees held their fall meeting simultaneously with an excellent attendance, reflecting not only the great amount of activity which is going on within the two committees but also an appreciation of the opportunity to visit these new laboratories. Subcommittee meetings were held on Monday, October 9, with the general meetings of each main committee on the morning and afternoon respectively of Tuesday, October 10. On the following day, Wednesday, October 11, an inspection trip was arranged by the PCA for all members interested in visiting the Naperville Test Farm where concrete specimens have been exposed to weathering action for several years.

Committee C-1 on Cement:

Committee C-1 had an attendance of 60 members with 29 visitors at its main meeting which followed a series of subcommittee meetings. Following the reading of a memorial resolution for the late H. D. Baylor, a long-time and prominent member of the committee, reports were presented by the several subcommittee chairmen. Some of the highlights of interest are reported here. In addition to its usual activities on chemical methods, the Subcommittee on Chemical Analysis is interested in a symposium on flame photometry. This symposium will be presented at the 1951 Annual Meeting and will be jointly sponsored by Committees C-1 and D-2 on Petroleum Products and Lubricants. One current study is an investigation of improved methods for manganese removal prior to the determination of calcium. A table was circulated with the subcommittee report which showed the results of comparative determinations on alkalies as tested by the ASTM referee and flame photometer methods, and indicated close agreement. The Subcommittee on Volume Change is currently working on an improvement of the autoclave method (C 151) and the tentative chemical reactivity method (C 227) for the purpose of presenting revisions which will give further refinement to these procedures. The subcommittee has completed a bibliography of papers on chemical reactivity and expects to complete a supplement to a previous summary on test methods which will be distributed to the committee. Normal consistency limits is one of the items now being considered by the Subcommittee on Time of Setting and data are being collected on the last of a series of cooperative tests, the data to be circulated to the committee. The Subcommittee on Heat of Hydration reported that three samples of moderate and low heat cement have been secured for cooperative tests among ten laboratories.

Considerable interest in the work was shown by an overflow attendance of the meeting of the Subcommittee on Bleeding. Workability studies are under way which include type of apparatus most suitable for use. The Subcommittee on Strength is now studying limitations of type and capacity of equipment for testing 2-in. cubes. Revisions of the new Tentative Specifications for Air-Entraining Additions (C 226) were submitted by the Subcommittee on Additions which will clarify and improve these specifications. The Subcommittee on Coordination of Methods of Tests is studying the problem of differences in behavior, after storage, of some lots of standard sand in the tests for air content of mortar.

The Subcommittee on Air-Entrainment Tests reported that arrangements were almost complete to begin extensive cooperative tests to find the proper method of determining air-content of cement in mortar.

The Subcommittee on SO_3 Content recommended for letter ballot of the committee a proposed tentative method of test for determining the presence of calcium sulfate in hydrated portland-cement mortar.

The adequacy of tensile and compressive strength specification limits were considered by the Sponsoring Committee on Portland Cement, but no change in the present limits was recommended. Further study and a report on merits of Flexure strength tests will be made by the Subcommittee on Strength. Consideration was also given to the gypsum requirement in the cement specifications, but until C-1 members have had time to study the results obtained by the new method for determining calcium sulfate in hydrated portland cement mortar, no action will be taken. The Sponsoring Committee on Blended Cement gave further consideration to changes in proposed specifications on fly ash and for portland fly ash cement. A series of tests will now be made in accordance with the revised specification requirements. A definition of the term "pozzolan" is being developed. The activities of the Cement Reference Laboratory for a six-month period were reported upon, the two main items being that the tenth inspection tour of laboratories had been started and that as a result of extensive study a flow-table calibration sample was now available for general distribution to interested laboratories.

The next meeting of the committee will be held in conjunction with the 1951 Spring Meeting of the Society in Cincinnati.

Committee C-9 on Concrete and Concrete Aggregates:

The meetings of Committee C-9 were also characterized by very good attendance. Included in the reports of the several subcommittees were the following items of interest. In the Research Group, the Subcommittee on Chemical Reaction of Aggregates in Concrete has continued to collect experience information and now will begin correlating this information to aid in the preparation of test methods to measure chemical reaction of aggregates. It was pointed out that such methods will be needed when consideration is given to a complete revision of the standard specifications for concrete aggregates (C 33). The Subcommittee on Durability of Concrete has discussed the effect of age at start of freezing and thawing tests and will prepare a written discussion of an outline prepared a year ago. Revisions of the tentative dynamic modulus of elasticity method (C 215) have been agreed upon by the sub-

committee and a draft will be circulated of proposed revisions (including the use of the oscilloscope) on types of pickup, tolerances, and calculation of correction factors. Research on the proper value of Poisson's ratio is being conducted, and a paper or report is to be prepared later. Torsional frequency will be considered and written either into the procedure of ASTM tentative method C 215 or as a separate method. A final draft of a list of descriptions of various types of rock for publication in the ASTM BULLETIN has been prepared and has been submitted to Society Headquarters. (Descriptions will appear in January BULLETIN.)

The subcommittees in the Specification and Test Method Group reported several items, including a proposed tentative specification on paper concrete-cylinder molds, which will be submitted initially to the manufacturers before committee action is suggested. A final draft of revisions of the method of test for volume change (C 157) was reviewed preparatory to letter ballot of the subcommittee. The Specifications for Concrete Aggregate (C 33) are being studied with the objective of complete revision to make this comprehensive standard a more complete and useful specification. Gradings for fine aggregates and chemical reactivity of aggregates are two items which are to be more fully covered. The need was expressed for a standard freezing-and-thawing test method to be included as a reference in this specification. The Subcommittee on Lightweight Aggregates reviewed a draft of a revision of the existing specifications (C 130). The final draft of the complete revision will be circulated as information to the members of the committee, after letter ballot in the subcommittee. The significant change in this specification classifies types of lightweight aggregate into two weight groups, one including aggregates in the range primarily suitable for acoustical and insulating purposes and the other group including those materials used where greater strength requirements are needed. A joint meeting was held by the Subcommittee on Admixtures with the Committee C-1 group on additions for the purpose of reviewing the differences between existing methods and specifications with the expectancy of reconciling these differences in future revisions. Coordination is also being effected between the subcommittee and the Sponsoring Committee on Blended Cement of Committee C-1 in developing standards on pozzolanic materials. The Specifications for Ready-Mixed Concrete (C 94) was reviewed by the subcommittee with discussion centering around two violations which persist; namely, that of overloading trucks and improper mixing time at central mixing plants. Manufacturers of equipment will be contacted to further establish the standards on load capacities of trucks. The Subcommittee on Miscellaneous Tests of Hardened Concrete is currently considering the effect of reactive aggregate on the method for determining cement content (method C 85) and is requesting the submission of additional samples of siliceous aggregates for cooperative tests.

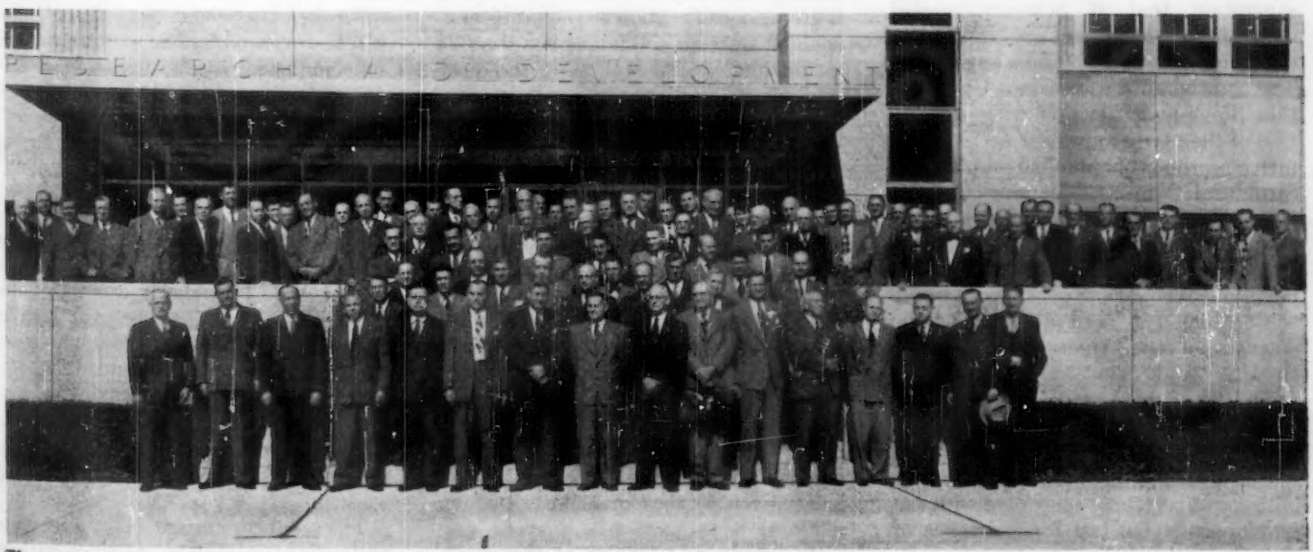
Three new subcommittees were authorized to be formed. A new subcommittee in the research group will collect data on permeability, heat evaluation, and fatigue of concrete. In the group on specifications and test methods, two subcommittees were authorized to work on test methods for resistance of concrete to abrasion and time of set of concrete, respectively.

The committee will meet during the Spring Committee Week of the Society in Cincinnati.

Chemical Resistant Mortars Group Holds Fall Meeting

THE fall meeting of Committee C-3 on Chemical Resistant Mortars was held at ASTM Headquarters on October 18. Several of the subcommittees held meetings preliminary to the main committee meeting. This committee is concerned with the preparation of specifications and necessary test methods on the several types of chemical-resistant mortars now in use.

The subcommittees which reported indicated concentration on methods of testing, especially those tests which are common to the several types of cements used. A proposed comprehensive standard covering methods of testing resin-type chemical-resistant mortars was reviewed which will include reference to setting time, tensile strength, compressive strength, flexural strength, bond strength, water absorption, chemical resistance, workability, and possibly shrinkage. Several of these specific property determinations still require development and others will make use of existing ASTM methods. The special subcommittee which is developing a method for working and setting time reported that it was considering the use of a recording viscometer to be used in preliminary tests to establish the suitability of this apparatus in a method. Three methods for bond strength have now been proposed for



The group shown are most of the members and visitors of the fall meetings of ASTM Committees C-1 and C-9 in front of the new Portland Cement Association Research Laboratories at Skokie, Ill., on October 9 and 10.

preliminary study: (1) one using a sandwich type specimen, (2) a method for cross brick, and (3) the ASTM method for air-setting refractory mortar (C 178).

The hydraulic mortar subcommittee has made excellent progress in proposing suitable methods of testing hydraulic mortars for resistance to various chemical reagents.

In considering miscellaneous applications which would fall within the present scope of the committee, it was felt appropriate to include tank linings (with and without brick and reinforcement), trench linings, wood covering, stack linings, and molded articles. In general, it was the consensus that the scope should be limited to materials which are placed by means of a trowel or pressure gun, but not to those which are applied by brush.

Toledo—Glass Committee

THE FALL meeting of Committee C-14 on Glass and Glass Products was held on the evening of October 6, 1950, at the Commodore Perry Hotel, Toledo, Ohio. The meeting followed sessions and a banquet of the Glass Division of The American Ceramic Society.

A brief review of the activities as noted from the several subcommittee reports is given below. The Subcommittee on Chemical Analysis is presently reviewing existing glass methods and is conducting round-robin testing for which three additional laboratories have volunteered their service and facilities. Cooperative work with the ASTM Committee C-7 on Lime is also progressing on a method for the determination of iron in lime. The Subcommittee on Physical and Mechanical Properties will study a suggestion that it consider needed methods on coefficient of expansion, softening point, and annealing point. The Subcommittee on Glass Construction Block and Tile, following completion of the newly approved ASTM Tentative Methods of Sampling and Testing Structural Non-Load-Bearing Cellular Glass Blocks (C 240–50 T), has been requested to submit a report on heat transfer through glass block. This report will be a review of comprehensive work which has been done under the auspices of the American Society of Heating and Ventilating Engineers (ASHVE) on heat transfer and will include recommendations for possible coordination with that organization. The special task group, under the Subcommittee on Flat Glass, concerned with the development of a test for resistance of glass to surface abrasion by measurement of its optical effects, reported that no decision has been reached on the acceptance of this test method. The data from the ASHVE as referred to above will also be studied in further consideration of this type of test. The preparation of a bibliography of available information of explosive effect on flat glass was suggested as a project for the Subcommittee on Flat Glass.

Committee on Refractories Holds 78th Meeting

THE 78th meeting of Committee C-8 on Refractories was held at Nittany Lion Inn, State College, Pa., on September 14. The activities of the several subcommittees were reported by the subcommittee chairmen and a few of the highlights of these activities is noted herewith.

The work of the Subcommittee on Industrial Survey is very comprehensive and is on a long-term basis. The surveys on the use of refractories in various industries, when prepared in written form, are an important part of the Committee C-8 compilation. Concerning these surveys, several existing reports are under revision, these including malleable iron, flat glass, coke ovens, and copper. New surveys are being prepared on the use of refractories in connection with incinerators, lead, and cupola installations. One new problem referred to the Subcommittee on Research is that of soliciting assistance in universities and other institutions for conducting research on the determination of crushing and transverse strength of refractories. Block density and porosity of granular materials still require attention.

In addition to the acceptance of editorial changes in the several spalling testing methods, the Section on Spalling is giving consideration to the problem of spalling tests on specimens less than $2\frac{1}{2}$ in. in thickness, as well as to the question of mortar for laying the panels in the test. A new definition of the term "spalling" has been prepared for acceptance which includes factors relating to spalling caused by thermal shock, structural changes, and mechanical conditions. A report was presented on temperature tests covering the completion of cooperative Pyrometric Cone Equivalent tests which contains much valuable data. Further tests are planned in the study to establish the advisability of changing the loading rate for the modulus of rupture tests (C 93) to a higher requirement. The Subcommittee on Heat Transfer reported on work being carried out at M.I.T. to develop a standard method of determining thermal conductivity, particularly on the pure oxide refractories. The Subcommittee on Special Refractories discussed in a report the possible revision of the term "special refractories," citing comments which have been received from both producers and consumers of refractory dolomite. In the light of these, the statement covering dead-burned refractory dolomite has been changed. The subject of mullite refractories was discussed and the several possible domestic sources were reviewed. The work of the committee in respect to carbon refractories is on a standby basis while close contact is maintained with the carbon research work of the American Iron and Steel Institute. The Subcommittee on Semi-Silica Brick is conducting an investigation of the possibility of using the 24-hr. load test as a means of classifying semi-silica brick. Results of tests conducted by the American Refractories Institute, as well as other tests, showed that the 24-hr. load test is not satisfactory for classification purposes. A paper has been prepared on this subject justifying the use of a minimum silica content requirement in a semi-silica brick classification. This paper will be reviewed by the members of the subcommittee.

Porcelain Enamel Committee Stresses Test Methods at Fall Meeting—Visits Westinghouse Plant

THE MANSFIELD, Ohio plant of the Westinghouse Electric Corp. was host to the members of Committee C-22 on Porcelain Enamel for the committee's fall meeting on October 12 and 13. Following a day of subcommittee meetings and a meeting of the main committee on the second day, an inspection trip was made through the plant with special attention being given to the porcelain enameling sections.

An interested observer at this meeting would certainly be impressed by the wholehearted interest shown and by the fact that the industry in general, in having ASTM standards, especially uniform methods of testing, will have a long-felt need fulfilled. Much was accomplished in the well-attended subcommittee meetings. Encouraging reports were presented at the main meeting, indicating considerable progress in this new field of ASTM standardization work.

The Subcommittee on Research, under G. H. McIntyre, received written reports on status of research covering

five subjects. These reports included characteristics of sheet metal surface for porcelain enameling; gas evolution effects associated with steel, enamel, and enamel processing; adherence and review of classification of porcelain enamels and ceramic coatings used at high temperatures. The Subcommittee on Nomenclature (F. A. Petersen, Chairman) reviewed the glossary orginally prepared by the American Ceramic Society and will now submit it for subcommittee letter ballot. The subcommittee has considered the advisability of preparing a glossary of trade names applying to materials used in the industry and as a result members will submit draft copies for consideration. The Subcommittee on Test Methods and Specifications, under Chairman R. F. Bisbee, reported through its three sections considerable progress in formulation of proposed test methods. The Sections on Raw Materials and Material in Process have combined their activities and have six assignments under way. Three of these are considered of short-term duration and include proposed methods covering screen tests for wet and dry mill enamel; fusion flow; and torsion tests. In the category of long-term projects will be proposed methods for measuring water for consistency of slip, the evaluation of enameling iron, and the tearing of enamel. The matter of determining the relative importance or significance of the several enameling tests will be referred to the research subcommittee. The Section on Finished Products has progressed to the point where it is expected that three proposed test methods will be available shortly for consideration by the subcommittee. These methods will cover the Enamel Utensils Manufacturing Council boiling acid resistance test, the E.U.M.C. impact test for holloware and the Porcelain Enamel Institute acid resistance test for flatware. Other test methods under consideration include those for abrasion, determination of thickness of porcelain enamel, gloss, reflectance, and adherence. Also included are those covering chemical attack, water and alkali resistance, scratch hardness, impact test for flat ware, and continuity of coating. An additional assignment, considered to be a difficult one, will be the development of a thermal shock test.

The committee will hold its next meeting during the 1951 Spring Committee Week in Cincinnati.

Committee B-4 Commemorates 25 Years' Service

COMMITTEE B-4 on Electrical Heating, Resistance, and Related Alloys held a Silver Anniversary Dinner on October 26, commemorating 25 years since the founding of the committee on October 27, 1925, in Cleveland.

The 55 members and guests in attendance were pleasantly carried back over the past years through a talk by Dean Harvey, long-time chairman and now Honorary Chairman of the committee and one of the original ten members of Committee B-4. Mr. Harvey pointed out that the committee was formed subsequent to a request to the Society that a specification be developed for electrical heating wires. Mr. Harvey first read a letter from H. L. Curtis, one of the two remaining members of the original committee, commenting on the growth and scope of work of the committee. In addition to the widespread use of the standards developed by this committee, both in this country and abroad, Mr. Harvey felt that the next most important thing to him was the spirit of cooperation which is prevalent among the members of the committee and that also important are the innumerable technical contacts that result from working with men interested in the same field of work.

Charles Banker of RCA delivered an interesting talk on industrial television. He pointed out that the field of industrial television is still in its infancy, but that many industrial organizations, hospitals, and similar interested groups are making plans for future installation of cameras. Some custom-made cameras have already been made, weighing 8½ lb. and only one twentieth as large as the ordinary commercial television camera. This camera uses the same type lens as used on a 16-mm. motion picture camera. On the receiving end, however, the ordinary television set now available on the market can be changed over to receive this wired television with a minimum of materials and labor. The camera itself is remotely controlled from a monitor.

Mr. Banker pointed out many possibilities for use of such an installation; in vehicular tunnels and bridges, cameras could replace a number of guards, leaving but a few at a central location to give instructions over a loud-speaker system for expediting the flow of traffic. For visual education, the applicability is practically unlimited. Medical students can be brought directly to the operating table; instructors can be used to teach more students; close-up views of dangerous experiments and demonstrations can be enlarged and projected for convenience and safety. Television in bank tellers' cages would make it possible to verify signatures directly from the bookkeepers' office. Likewise, signed documents and security passes into restricted areas can be scrutinized from a remote point. The underside of rolling stock can be inspected; conditions in furnaces can be observed; tests of combustion products in jet engines and rockets can be analyzed.

Although only a few cameras and monitors have been custom made for the armed services, production should be standardized in the near future and industrial television made available to industries as a whole. Subsequent to his talk, Mr. Banker and his assistant, George Closs, televised a number of those present and explained in some detail the workings of the camera and the monitor.

Buffalo Meeting—Metallic Coatings Committee

COMMITTEE B-8 on Electrodeposited Metallic Coatings held a 3-day meeting in Buffalo, New York, October 9–11, 1950.

At the meeting an intermediate report was presented on atmospheric exposure tests of copper-nickel-chromium platings. A 500-hr. laboratory salt spray test of various coatings showed no correlation with actual atmospheric exposure performance. It is suggested that although a salt spray test may be excellent for locating pinholes and other plating irregularities it is not a quick, accurate test for determination of coating *performance* if the coatings are uniform.

The results of preliminary experiments concerning nickel-chromium platings on brass, show no differences due to the use of different surface finish treatments of the base metal. This bears out the work at the National Bureau of Standards in plating various finishes of cold-rolled steel.

Recommended practices for preparation of surface and plating on stainless steel, preparation of aluminum for electroplating, and preparation of zinc-base die castings for plating have been prepared and will be submitted to the committee as a whole for approval. Work is still progressing on recommended practices for preparation of plastics for electroplating and preparation of copper and copper alloys for electroplating.

Task groups have been appointed to survey the need of recommended practices for preparation of lead alloys for

"Loss by Corrosion"

An interesting photograph displayed in the General Section of the Seventh ASTM Photographic Exhibit in Atlantic City, by William W. C. Wilke, Jr., Crane Co.

plating, preparation of tin and tin alloys for plating, and preparation of cast and malleable iron for plating. Exposure tests are being planned for two electrochemical and three dipped chromate finishes on zinc plating. The effects of the salt spray tests on various thicknesses of phosphate coatings are also being studied. There was some discussion of the ASTM salt-spray requirement of 24 hr. as compared with the proposed Federal specification of 96 hr.

Committee B-8 is considering standardization of significant figures in the various specifications under its jurisdiction. All thickness values will be given in both English and metric units. The values in both cases will be given to two significant figures.

Specifications A 164, A 165, and A 166 are being reviewed so that they will be more applicable when used for plating threaded fasteners.

Electrical Heating Alloys Committee Meets

COMMITTEE B-4 on Electrical Heating, Resistance, and Related Alloys held a two-day meeting at ASTM Headquarters on October 26 and 27. A highlight of the meeting was the Silver Anniversary Dinner held on October 26 (See article, "Committee B-4 Commemorates 25 years Service," which appears on p. 21.)

This committee is revising Specifications B 82 (80 per cent Ni and 20 per cent Cr) and B 83 (60 per cent Ni and 16 per cent Cr) on electrical heating elements to include a method of calculating dimensional tolerances for resistance wire and ribbon where such tolerances may be required. Subcommittee V on Wrought and Cast Alloys for High-Temperature Use is surveying the high-temperature alloy field to develop a new work program.

A survey is also to be conducted of users and producers of alloys having low thermal expansion to determine if there is sufficient interest to warrant writing of specifications for such materials.

Since the last meeting of the committee, revisions have been made in Methods for Testing Thermostat Metals (B 106–40) and in the Tentative Method of Test for Modulus of Elasticity of Thermostat Metals (B 223–48 T) so that size requirements will approach more closely standard test samples used by industry. The committee is continuing its work on the effect of various furnace gases on standard alloys and is endeavoring to correlate data showing the effect of gases on standard alloys as a function of the temperature. Also being studied is the effect of oxidation and carbon pickup. Committee B-4 is working with Committee E-1 on methods of hardness testing and has suggested to E-1 that work be undertaken on the study of micrometers. It was announced that the 1949 Supplement to the Bibliography and Abstracts on Electrical Contracts is now available.

Committee B-4 has made an extensive study of the Methods of Measuring Mica Stampings Used in Electronic Devices and Incandescent Lamps (D 652–43) prepared by Committee D-9 on Electrical Insulating Materials. Proposed revisions of this method have been sent to Committee D-9 and are now being reviewed by that committee.

A round-robin test on the weighing of fine wire is being conducted among a number of companies to determine variations in weighing by different operators. If fine wire can be weighed by different operators with small variations, weight and density can be used to calculate fine wire size more accurately than trying to measure actual diameters.

Subcommittee VIII on Metallic Materials for Radio Tubes and Incandescent Lamps appointed five new task groups as follows:

Rate of Cathode Activation
Rate of Free Barium Evolution and Emission Life
Interface Resistance
Rate of Sublimation
Chemical and Gas Analysis

It was agreed that the next meeting of the committee should be held in the New York area in February.

Committee D-15 on Engine Antifreezes

COMMITTEE D-15 on Engine Antifreezes and its seven subcommittees held a two-day series of meetings in New York, on October 19 and 20. Consideration was given to the several cooperative test programs under way as well as to progress reports on other active projects.

A report from the Study Group on Corrosion and Foaming Test Methods presented the first results of the cooperative test program for evaluating antifreezes by laboratory glassware type screening tests and by a simulated type dynamometer test. Twelve laboratories are cooperating in the beaker type corrosion test. The test methods employed covered a considerable range of conditions ranging from 160 F. nonaerated tests in large test tubes to an oxygen bomb test at 135 psi. and 212 F. All tests were similar in that they involved immersion of assorted test specimens in heated test solutions for a specified period of time after which corrosion was measured, generally by weight loss. Eight laboratories are also cooperating in the bench type circulating test in which three antifreezes are being evaluated. The three test fluids consist of two glycol-base antifreezes and one salt-base material. So far results have been reported by 40 per cent of the cooperating laboratories. The data pre-

sented in this progress report represent a real start in attempting to define the problems in evaluating an antifreeze by a laboratory test method. There still remains considerable work to be done before entirely satisfactory test methods can be devised.

The Subcommittee on Freezing Point Determination submitted a new method for determining this property of engine antifreezes for publication as tentative, subject to favorable letter ballot of the subcommittee and Committee D-15. The method has been tried out by extensive cooperative tests. At the Annual Meeting of the Society in June a paper on "The Determination of Freezing Point of Engine Antifreezes" was presented by R. E. Mallonnee, National Carbon Co., Inc., and F. L. Howard, National Bureau of Standards, which paper contained a summary of the work of the subcommittee.

Subcommittee II on Antifreeze Field Testers has prepared the new Tentative Specifications for Hydrometer-Thermometer Field Tester for Engine Antifreezes (D 1124 – 50 T). This tester is for use in the new freezing point method.

Subcommittee III on Physical Properties has prepared the new Tentative Methods of Test for Boiling Point of Engine Antifreezes (D 1120 – 50 T) and for Specific Gravity of Concentrated Engine Antifreezes by the Hydrometer (D 1122 – 50 T). The boiling point method is being studied by cooperative tests for application to concentrated antifreeze. Further collaborative work is being conducted to obtain reproducibility limits for Method D 1120. Laboratory studies of the specific gravity method are being conducted to determine if this method can be modified for application to testing dilute antifreeze. The subcommittee is also investigating the reproducibility of the measurement of specific gravity of hot antifreeze solutions.

Subcommittee IV on Chemical Properties prepared the new Tentative Methods of Test, for Water Content of Concentrated Engine Antifreezes by the Iodine Reagent Method (D 1123 – 50 T), for Ash Content of Concentrated Antifreezes (D 1119 – 50 T), and for Reserve Alkalinity of Concentrated Antifreezes (D 1121 – 50 T). Work is under way on a method for the determination of pH of engine antifreezes which will make use of the Tentative Method for Determination of the pH of Aqueous Solutions with the Glass Electrode (E 70 – 46 T).

Subcommittee V on the Effect of Antifreeze on Rubber Hose is preparing a program of work.

Adhesive Committee Meets—Boston

ALL subcommittees of Committee D-14 on Adhesives held well-attended meetings during the two-day meeting of the committee on October 19 and 20 at the Hotel Statler, Boston, Mass. A luncheon was held on the second day with an attendance of over fifty persons. Following the main meeting on October 20, Prof. A. G. H. Dietz of the Massachusetts Institute of Technology gave an illustrated talk on the research being conducted at the Institute as one of the projects of the Ordnance Advisory Committee on Adhesives.

The Subcommittee on Strength Tests reported the following items: a proposed method for flexural strength will be recommended to the Society; a proposed shear strength method on plastic-to-plastic adhesives, which is the fourth of a series of shear tests is being developed; an improved method for impact strength based on the new design of a jig has been prepared for committee letter ballot; a simplified test for the measurement of the tensile strength of wood adhesives is being considered with further round-robin tests proposed for the collection of additional data, following which a proposed method will be submitted to the subcommittee for letter ballot. It has been concluded that the 90-deg. peel test is more suitable than the 108-deg. test. To date tests on the 90-deg. method have given inconsistent results but further study will be given to development of a procedure. A British method has been suggested for consideration in this study.

In the meeting of the Subcommittee on Electrical Properties it was reported that a test method on insulation resistance is being developed on which round-robin tests will be conducted. The section on arc resistance is coordinating its activity with that of ASTM Committee D-9 on Electrical Insulating Materials. Round-robin tests on adhesives have been suggested using the tentative ASTM Method D 495. The subcommittee on Tests for Permanency has reviewed a proposed tentative method of test for resistance of adhesives for wood to cyclic accelerated service conditions. It was agreed to include the cycles of 24 and 48 hr. Each will be run at 77 and 120 F., respectively, with two of the cycles being run at 85 to 90 per cent relative humidity. It was also agreed to use the per cent of original value as a standard for expressing the relationship. A procedure for continuous exposure to temperature and humidity effects was accepted as a recommended practice. The subcommittee has recommended for advancement to standard the Tentative Method of Test for Resistance of Adhesive Bonds to Chemical Reagents (D 896). The need for study of further factors involved in the effect of light on permanence was emphasized on the basis that the present method is not adequate. Drafts of several methods on effect of biological factors have been prepared for consideration. Participation in the use of ASTM corrosion test sites was discussed and the section was authorized to circularize industry to establish the latter's interest in participating in the test site program. The collection, review, and dissemination of data collected would be controlled by the committee with the understanding that such data are to be made available for publication. A proposed method for consistency measurements was reviewed and approved for submittal to letter ballot of the committee. Five tackmeters have been built in accordance with the approved design, thus enabling round-robin testing to be undertaken. The proposed method of test for blocking has been accepted by the committee and will be submitted to the Society. Discussion took place on the need for definitions of the terms "slippage" and "flow" and on the possible use of the parallel-plate plastometer, now used in the glass industry, for adaptation to the testing of adhesives for these properties.

A meeting of great interest to the committee as a whole was held by the Subcommittee on Specifications; reports were received from the several sections dealing with specific fields of use for adhesives. A proposed specification for general-purpose adhesives has been agreed upon for submittal to letter ballot of the subcommittee. Considerable progress was reported in the development of a specification for bookbinding adhesives. A survey has been made of the various properties for which test methods and limitations should be established in the development of a suitable specification. It was found that the present ASTM test methods developed by the committee will lend themselves very readily for reference in such a specification. A survey has been made of the types of adhesives used for packaging purposes and the kind of material on which they are applied. A new section is to be organized to investigate the feasibility of writing a specification on wood adhesives. It is planned to conduct further round-robin tests for checking a proposed specification on acoustical tile adhesives.

The Subcommittee on Analytical

Tests is considering a proposed method of test for the determination of solids in urea resins. The Subcommittee on Nomenclature plans to submit a tentative list of additional definitions for letter ballot with the consideration being given to such terms as permanence, plasticizer, and consistency.

The Subcommittee on Research gave further discussion to the subject of pure shear in which it was pointed out that it would be desirable to have a factor to relate pure shear with tensile strength. Comments were requested on a proposed program for the investigation and development of evaluation procedures for wood adhesives to be conducted at the Engineering Research Inst., University of Michigan. Discussion also took place on the subject of fundamental work of adhesion.

The 1951 meetings of the committee are planned to be held in Washington, D. C., in April and the fall meeting in Detroit in October.

Shipping Container Group Meets in Philadelphia

THE regular fall meeting of Committee D-10 on Shipping Containers on October 12 and 13, 1950, at Society Headquarters, was augmented by a plant visit and luncheon at the Crown Can Co. and by some stimulating remarks from C. L. Warwick, Executive Secretary of the Society, at the start of the main meeting. In welcoming the group to Headquarters, Mr. Warwick commended the committee members for their contributions to the field of shipping container standardization and emphasized that the resources of the Society are available at any time and in any way necessary to further the work of Committee D-10.

The committee scope has been broadened to cover "nomenclature, definitions of terms, test methods, performance specifications, and study of the effect of various factors influencing strength and serviceability relating to packaging, including packages, shipping containers, and pallets." At the meeting it was announced that a conference held with representatives of the Packaging Institute in August resulted in agreement to facilitate interchange of ideas and avoid duplication of efforts in packaging standardization. A feature of the main meeting was a talk "Nature of Shock and Difficulties in Its Measurement" delivered by Frederick D. Schottland, who was introduced to the group by George D. Nutting.

At the main meeting the committee voted to advance to standard two tentative methods, for penetration of liquids in submerged containers, D 998, and for water resistance of containers by the spray method, D 951. The definitions relating to shipping containers will be extended to include a new glossary of terms on interior packing which has been prepared by Subcommittee VI on Interior Packing and is now being reviewed by Subcommittee I on Definitions. In reporting on the new field of standardization of pallets, five proposed test methods were discussed and several revisions were agreed upon. It was suggested that an additional vibration test be specified to permit the use of equipment having capacities limited to 1000 lb. together with the vibration test as described in the proposed methods. The changes to the proposed test methods will now be reviewed by the Section on Pallets. The two tentative test methods, for water vapor permeability of packages, D 895, and for water vapor permeability of shipping containers, D 1008, were recommended for retention as tentative pending discussion with TAPPI on agreement of details of the methods proposed by TAPPI and ASTM. This is in accordance with the policy of the committee to minimize duplication between ASTM and other organizations working in the same field.

At the meeting of Subcommittee IV on Performance Standards, S. G. Guins summarized his study of shock and vibration in railroad trucks. His findings will be added to the committee's growing store of experience and will be applied to the later development of standards. As a result of some discussion on performance standards, it was agreed to recognize four types of handling: (1) domestic—car, truck, or plane load, (2) domestic—less than car, truck, or plane load, (3) export—commercial, and (4) military. It is felt that this subject needs careful study and that performance standards should be set up on the test-by-test basis and that general performance standards which would apply to all tests could not be set up at this time.

Subcommittee V on Correlation of Tests and Test Results reported that final details are being worked out in a round-robin test series now under way using the revolving drum apparatus. This drum test will be extended to include wire-bound boxes in the 7-ft. drum. The drop test will be the next project to be investigated for correlation among laboratories. Information is being collected on the box compression test, and this information will be used, if possible, by the subcommittee to obtain the coefficient of variance within the laboratories and between the laboratories conducting the tests. Work will now begin, in Subcommittee VI on Interior Packing, on new test methods for evaluation of cushioning materials, abrasive characteristics of cushioning materials, for press marking of high-finished surfaces by cushioning materials, and for determination of resistance of carton printing to scuffing.

It was the consensus of the committee that the spring meeting of the committee should be held in conjunction with the American Manufacturers Assn. Packaging Show at Atlantic City, and it is planned to hold the meeting on April 16 and 17 at the Claridge Hotel.

SAMA Broadens Standardization Efforts

THE mid-year meeting of the laboratory apparatus and optical sections of the Scientific Apparatus Makers' Association (SAMA) was held in September in Hot Springs, Va.

Renewed efforts will be made during the coming year by the committee on standardization to find areas of agreement for the elimination from manufacturers' catalogs of slow moving items which plague both manufacturers and dealers. Efforts will also be made to cut down the number of sizes and shapes in an effort to alleviate the troublesome stock and inventory problems confronting dealers.

Chairman T. M. Mints, President of E. M. Sargent & Co., in his report pointed out that the committee has decided to concentrate its efforts along simplification lines on manufacturers rather than with dealers, pointing out that many manufacturers have not issued catalogs recently, that there are fewer manufacturers than dealers, and that manufacturers know better the demand for their products and also are in a position to know definitely whether a specific item has sufficient demand for an economical run in the factory.

In his report Mints recalled his experiences in Germany immediately following the recent World War . The German factories in this field instead of adding to their lines did the reverse and actually reduced the number of items and sizes of items that they offered for sale. This program permitted larger production runs of fewer items, offered better service to the trade, and reduced manufacturing costs.

Three subcommittees of the standardization committee have been formed with B. Fisher as chairman of the subcommittee handling glassware; Robert Eberbach, chairman of the committee investigating metal ware; and Clarence Schaar, chairman of the subcommittee studying rubber goods.

After the three subcommittees have studied their lines with the respective manufacturers and have arrived at recommendations, their report will be submitted to the standardization committee, and then consolidated with the complete report. The SAMA recommendations will be reviewed with the Standardization Committee of the American Chemical Society.

PERSONALS . . .

News items concerning the activities of our members will be welcomed for inclusion in this column.

NOTE—These "Personals" are arranged in order of alphabetical sequence of the names. Frequently two or more members may be referred to in the same note, in which case the first one named is used as a key letter. It is believed that this arrangement will facilitate reference to the news about members.

Various Members Honored or Active in National Metal Congress

A GREAT many members of ASTM are also very active in various professional and technical groups including the societies which meet during the Annual National Metal Congress. Here are some notes on ASTM members or committee members who were prominent during the recent Congress held in Chicago in October.

Earle C. Smith, Chief Metallurgist, Republic Steel Corp., presented the ASM Campbell Memorial Lecture which is this society's most important scientific presentation. It is of interest to note that Mr. Smith, widely known in the industry, carried out graduate work in metallography at Columbia under Professor Campbell, in whose honor the Lecture was established. Messrs. **W. O. Binder,** of Union Carbide and Carbon Research Laboratories, Inc., and **Russel Franks,** of the Electro Metallurgical Co., with C. M. Brown, were cited for the best paper in the 1949 ASM *Transactions.* This was entitled "Resistance to Sensitization of Austenitic Chromium-Nickel Steels of 0.03% Max. Carbon Content." Two new trustees of the American Society for Metals are **Dr. J. T. MacKenzie,** Technical Director, American Cast Iron Pipe Co., very active in ASTM and a former member of the Board of Directors, and **Dr. J. B. Austin,** Director of Research, U. S. Steel Corp., Research Laboratories.

Harry W. Pierce, Assistant to President, New York Shipbuilding Corp., was installed as President of the American Welding Society for 1950–1951. **Fred L. Plummer,** Director of Engineering, Hammond Iron Works, Warren, Pa., will serve as second Vice-President of AWS for the coming year. New directors include **LaMotte Grover** of Air Reduction Sales Co., **H. E. Rockefeller** of The Linde Air Products Co., and **J. R. Stitt** of R. C. Mahon Co. **Wendell F. Hess,** Head, Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, was recipient of the AWS Samuel Wylie Miller Memorial Medal "for his conspicuous contributions to the advancement of welding and cutting of metals." **Howard S. Avery,** Research Metallurgist, American Brake Shoe Co., was winner of the 1950 AWS Lincoln Gold Medal, awarded annually to the author of the paper judged the greatest original contribution to the advancement and use of welding. Mr. Avery's winning paper, "Hot Hardness of Hard Facing Alloys," was published in the July, 1950, issue of *The Welding Journal.*

W. E. Thomas, Vice-President, Magnaflux Corp., was elected President of the Society for Non-Destructive Testing for 1950–1951, and **Noah A. Kahn,** Principal Metallurgist, New York Shipyard, was named Vice-President; **Robert C. McMaster** of Battelle Memorial Institute was elected Treasurer. New directors of this society include **Gerold H. Tenney,** Los Alamos Scientific Laboratory, and **William C. Hitt** of the Douglas Aircraft Co.

Other ASTM members who were prominent during the Metal Congress included **O. B. J. Fraser,** International Nickel Co., and **Leslie W. Ball,** Naval Ordnance Laboratory, retiring presidents, respectively, of the American Welding Society and the Society for Non-Destructive Testing. **Bruce W. Gonser** of Battelle Memorial Institute, had an active part in the ASM lecture series.

Thomas H. Briggs is now Research Engineer, Special Devices Dept., Research Division of the Burroughs Adding Machine Co. Formerly he was Electronics Engineer, Superior Tube Co., Norristown, Pa. Mr. Briggs is heading up important work in ASTM Committee B-4 on Electrical Heating, Resistance, and Related Alloys, which involves metallic materials for radio tubes and incandescent lamps, specifically work on cathode. Mr. Briggs received degrees from Wesleyan University and the California Institute of Technology.

Chester R. Austin has been appointed Manager, Development Section, Research Dept., Koppers Co., Inc., Pittsburgh, Pa. Prior to joining the company in 1948 he was engaged in ceramic research at Battelle Memorial Institute.

Wayland S. Bailey, formerly on the faculty of the Massachusetts Institute of Technology, Cambridge, is now Associate Professor of Mechanical Engineering, Norwich University, Northfield, Vt.

Loren V. Burns, formerly Vice-President and Technical Director, Spear Mills, Inc., is now Owner, Loren V. Burns & Associates, Kansas City, Mo.

Laurence H. Carr, previously Chief Metallurgist, has been named Director of Engineering and Research for Edward Valves, Inc., East Chicago, Ind. A member of the company's technical staff since 1936, Mr. Carr in his new position will be responsible for consolidating the development functions of engineering research, product engineering, and technological specifications for process control.

George S. Cook is now associated with the General Electric Co., Scotia, N. Y. He was formerly Paint Technologist, Engineer Research and Development Lab., Ft. Belvoir, Va.

Clyde A. Crowley has been named President, Graham, Crowley and Associates, Inc., Chicago, Ill. He was previously with the Technical Service Bureau, Inc., Chicago.

W. F. Fair, Jr., Supervisor of the Westfield, N. J., Laboratory, Tar Products Division of Koppers Co., Inc., and Advisory Fellow at Mellon Institute in Pittsburgh, was recipient of the 1950 Bingham Medal of the Society of Rheology "for notable contributions to colloid chemistry, to the technology of bituminous materials, and to the science of rheology."

Robert A. Fitch has been promoted by Gulf Oil Corp. and Gulf Refining Co. from Lubrication Engineer in the New York Division office to Chief Fuels and Lubricants Engineer, Metallurgical Section, Industrial Products Engineering Dept.

Lyman Fourt, Research Associate, Harris Research Laboratories, Washington, D. C., and **H. F. Mark,** Director and Professor of Organic Chemistry, Institute of Polymer Research, Polytechnic Institute of Brooklyn, have been elected to Fellowship in the International Textile Institute, Manchester, England.

Harry Kline, formerly Manager and Technical Director of the Phenolics Plastics Division of Reichhold Chemicals, Inc., Detroit, Mich., has been elected a Vice-President of the company.

W. B. Kouwenhoven, Professor of Electrical Engineering and Dean, School of Engineering, Johns Hopkins University, Baltimore, Md., was co-recipient with W. T. Sackett, Jr., Battelle Memorial Institute, of a $250 prize awarded by the American Welding Society in the 1950 Resistance Welder Manufacturers Association prize contest. Their paper was entitled "Electrical Resistance Offered to Non-Uniform Current Flow."

Roman Smoluchowski, Professor of Metallurgical Engineering at Carnegie Institute of Technology, has been appointed as a consultant to the chairman of the Research and Development Board, Washington, D. C. He will consult on matters pertaining to the physics of solids while retaining his position at Carnegie Tech.

The **Superior Tube Co.,** Norristown, Pa., has announced that Philip N. Hambleton, formerly of the Philco Tube Development Laboratory, has been appointed Electronics Engineer in charge of the company's Electronic Laboratory.

Raymond Szymanowitz, Vice-President in Charge of Research, Acheson Colloids Corp., Newark, N. J., has been elected a Director of Acheson Colloids Limited, of London, England. He has been with the Acheson Corporation since 1924, and for many years was a part-time instructor in the Department of Chemical Engineering at Cooper Union.

A. Frank Tesi, formerly with W. T. Grant Co., New York City, is now Assistant to Technical Officer, Celanese Corp. of America.

A prominent figure in the field of textile technology, Dr. Tesi served for two years as head of the consumer Standards Division of the American Standards Association, and for fourteen Years held a Commodity Standards Fellowship at the Mellon Institute.

Fred Thatcher, Chief Chemist, Carnegie-Illinois Steel Corp.'s Clairton, Fa., By-Products Coke Plant, has been elected President of the Eastern States Blast Furnace & Coke Oven Association.

The many friends and committee associates of **Wally Warner,** of the Inland Steel Co., Chicago, who has been at home for several weeks recuperating from a heart condition, will be interested to know that he is continuing to make progress. Wally has done yeoman work as the Vice-Chairman and Secretary of the Steel Committee's Subcommittee XI on Materials for Pressure Vessels, particularly plates. This group has had an intensive program of modernizing specifications under way. His home address is 504 S. Elmhurst Road, Mt. Prospect, Ill.

NEW MEMBERS . . .

The following 61 members were elected from September 11, 1950, to November 8, making the total membership 6811 . . . Welcome to ASTM

Note—Names are arranged alphabetically—company members first then individuals

Chicago District

CHRISTIANSEN CORP., Edward S. Christiansen, President, 1515 N. Kilpatrick Ave., Chicago 51, Ill.

ENTERPRISE PAINT MANUFACTURING CO., Arthur F. Bohnert, Technical Director, 2841 S. Ashland Ave., Chicago 8, Ill.

NUCLEAR INSTRUMENT AND CHEMICAL CORP., John L. Kuranz, Vice-President, Technical Div., 223 W. Erie St., Chicago 10, Ill.

PROMAT DIVISION, POOR AND CO., A. E. Chester, Director of Research, 851 S. Market S., Waukegan, Ill.

PULLMAN STANDARD CAR MANUFACTURING CO., D. A. Hilliard, Paint Consultant, R. & D. Dept., 1414 Field St., Hammond, Ind.

TESTWORTH LABORATORIES, INC., W. E. Higbee, Technical Director, 407 S. Dearborn St., Chicago 5, Ill.

CAIN, CRAIG J., Manager, Combustion By-Products Co., 228 N. LaSalle St., Chicago 1, Ill.

ERICSON, HARRY L., Chief Rubber Chemist, Witco Chemical Co., Technical Service Lab., 6200 W. Fifty-first St., Chicago 38, Ill.

SENKUS, MURRAY, Director of Research and Development, Nox-Rust Chemical Corp., 2429 S. Halsted St., Chicago 8, Ill.

ZERKEL, JOSEPH A., Metallurgical Engineer, Milwaukee Forge and Machine Co., 1532 E. Oklahoma Ave., Milwaukee 7, Wis.

Cleveland District

CARVER, L. D., Technical Sales Manager, Continental Carbon Co., 311 Evans Bldg., Akron 8, Ohio.

CRAMER, WILLIS T., Division Metallurgist, American Steel and Wire Co., Rockefeller Bldg., Cleveland 13, Ohio.

RAWSON, G. R., Division Metallurgist, American Steel and Wire Co., Rockefeller Bldg., Cleveland 13, Ohio.

TREIBER, O. D., Consulting Engineer, Hercules Motors Corp., 101 Eleventh St., S.E., Canton, Ohio. For mail: 1414 Ridge Rd., N.W., Canton, Ohio.

Detroit District

MYERS, HOMER S., Vice-President, Radioactive Products, Inc., 443 W. Congress St., Detroit 26, Mich.

New England District

HARTFORD ELECTRIC STEEL CORP., C. D. Berry, Works Manager, 540 Flatbush Ave., Hartford, Conn.

LEE LIME CORP., John Gaisford, Chemist, Lee, Mass.

BARLOW, FRED W., In Charge of Rubber and Plastics Testing Lab., Godfrey L. Cabot, Inc., 49 Beach St., Boston 10, Mass.

CARPENTER, LLOYD W., In Charge of Paper Twisting Div., Plymouth Cordage Co., N. Plymouth, Mass.

KOBAYASHI, FRITZ F., Chemist, Ames Worsted Co., Lowell, Mass.

MCLEOD, WILLIAM WATSON, Structural Engineer, Providence Steel and Iron Co., Box 1306, Providence, R. I.

ROSS, ARTHUR I., Chief Chemist, Panther-Panco Rubber Co., Chelsea, Mass.

New York District

ALLIED ASPHALT AND MINERAL CORP., J. R. Davidson, Sales Manager, 139 South Ave., Dunellen, N. J.

FABRIKANT STEEL PRODUCTS, INC., William Fabrikant, Secretary-Treasurer, 233 Broadway, New York 7, N. Y.

GEIGER, CHARLES F., Technical Manager, Refractories Div., The Carborundum Co., Box 268, Perth Amboy, N. J.

HADDOCK, GERALD T., American Representative, Lafarge Aluminous Cement Co., Ltd., 247 Park Ave., New York 17, N. Y.

LIPPERT, THOMAS W., General Manager, Titanium Metals Corp., 60 E. Forty-second St., New York 17, N. Y.

LUSTER, D. R., Remington Arms Co., Inc., Bldg. 368, Bridgeport, Conn.

WHALEN, J. T., JR., President, Accurate Insulated Wire Corp., 25–45 Fox St., New Haven, Conn. For mail: Box 13, New Haven 13, Conn.

Northern California District

PRIOR, HUGH F., Foundry Superintendent, Superior Electrocast Foundry, Harbor Blvd., S. San Francisco, Calif.

Ohio Valley District

FOX, EDWIN H., General Manager, The Cincinnati Concrete Pipe Co., Box 65, Cincinnati 15, Ohio.

HAZELET, CRAIG P., Consulting Engineer, Hazelet & Erdal, 1614 Heyburn Bldg., Louisville, Ky.

KRAUSE, DANIEL E., Executive Director, Gray Iron Research Inst., Inc., 1300 Grandview Ave., Columbus 12, Ohio.

Philadelphia District

MILLARD LIME AND STONE CO., H. E., David K. Shroyer, Sales Manager, Annville, Pa.

BAILEY, S. DAVID, Head, Physical Chemical Section, Smith, Kline and French Labs., 1530 Spring Garden St., Philadelphia, Pa.

FRY, H. L., Foreman of Special Tests, Bethlehem Steel Co., Inc., Bethlehem, Pa.

HORN, RUSSELL E., Registered Engineer, Buchart Engineering Corp., 611 W. Market St., York, Pa.

HOWELLS, EDGAR H., Assistant Metallurgical Engineer, Bethlehem Steel Co., Bethlehem, Pa.

KINNEY, HARLIN S., Chemist, H. E. Millard Lime and Stone Co., Annville, Pa. For mail: 51 W. Sheridan Ave., Annville, Pa.

SPENCER, WILLIAM C., JR., Product Manager, Horace T. Potts Co., Erie Ave. and "D" Sts., Philadelphia 34, Pa.

To the ASTM Committee on Membership

1916 Race St., Philadelphia 3, Pa.

Gentlemen:

Please send me information on membership in ASTM and include a membership application blank

Signed _____

Address _____

Date _____

Pittsburgh District

FISHER SCIENTIFIC CO., J. W. Geisler, Petroleum Apparatus Engineer, 711 Forbes St., Pittsburgh 19, Pa.
MERCER TUBE AND MANUFACTURING CO., Lynn C. Davenport, Superintendent, 200 Clark St., Box 536, Sharon, Pa.
ROBERTSON, H. H., Co., A. W. Coffman, Vice-President in Charge of Research and Development, 2400 Farmers Bank Bldg., Pittsburgh 22, Pa.

Southern California District

CARY, HOWARD, President, Applied Physics Corp., 30 W. Green St., Pasadena, Calif.
SHANKMAN, SOLOMON, Director, Shankman Labs., 2023 Santa Fe, Los Angeles 21, Calif.

Washington (D. C.) District

DICKERSON, N. K., SR., Contractor, Dickerson, Inc., Monroe, N. C.
GARDNER, HENRY ALFRED, JR., Treasurer, Henry A. Gardner Lab., 4723 Elm St., Bethesda 14, Md.

U. S. and Possessions

BATES, JAMES P., Chief Metallurgist, Hyster Co., Portland 8, Ore. For mail: 4141 S. W. Pendleton St., Portland 19, Ore.
BURKE, JOHN G., President, Dry Ice Converter Corp., Box 1652, Tulsa 1, Okla.
HARGAN, J. A., Head, Engineering Dept., Todd-Johnson Dry Docks, Inc., Box 239, New Orleans 3, La.
SWANSON, HENRY W., Asphalt Engineer, Berry Asphalt Co., Magnolia, Ark. [J]*.
WILSON, THOMAS W., Director of Research, The McCormick Spinning Mill, Inc., McCormick, S. C.

Other than U. S. Possessions

IMPERIAL CHEMICAL INDUSTRIES, LTD., PLASTICS DIV., A. H. Willbourn, Black Fan Rd., Welwyn Garden City, Hertforshire, England.
BERGSMAN, ENAR BORJE, Chief Metallurgist, Svenska Metallverken, Vasteras, Sweden.
ELISSAGUE, JOSE MARTINEZ, Civil Engineer, Condesa No. 6-701, Mexico 1, D. F., Mexico.
FOSTER, THOMAS CROWEST, Engineer Inspector, c/o Foster Wheeler, Ltd., Shell Refining and Marketing Co., Ltd., Stanlow, Cheshire, England.
GRIFFITHS, D. W., Technical Director, Glazebrooks Paints, Ltd., 269 Williamstown Rd., Port Melbourne, S.C. 7, Australia. For mail: Greythorn Rd., North Balwyn, Melbourne, Australia.
PATERSON, L. M., Managing Director, The Bifurcated and Tubular Rivet Co., Ltd., Fox Hill, Aylesbury, Bucks, England.
SIMON, PEDRO M., Chemist, J. Simon y Cia., Falgueras 201, Cerro, Havana, Cuba.
VAN DER WOUDE, CATO AART ADOLPHE, Acting Director, Laboratory for Testing Materials, 10 Djalan Sekolah Tinggi Bandung, Java, Indonesia.
WALZ, KURT, Professor, Institute for Building Research, Stuttgart, Cannstatter-Strasse 212, Germany.

* [J] denotes Junior Member.

John W. Sifton New Member of Headquarters Staff

JOHN W. SIFTON, formerly in the advertising department of a large manufacturer of machinery, joined the Headquarters Staff in Philadelphia on August 1 to aid the assistant Secretary in advertising, membership, and other developmental activities. A graduate of Newton High School in Elmhurst, L. I., Mr. Sifton attended Hamilton College majoring in English in the Liberal Arts Course. His college work was interrupted by several years in the Army Air Force where he served from January, 1943, through March, 1946, being a qualified weather observer and spherics observer. For many months he was in China. Following graduation from college he spent several months in Alaska with a gold dredging concern, and then entered the employ of an eastern machinery and equipment manufacturer.

His work will involve advertising contacts with the companies in the instruments and laboratory supplies field; he will aid in planning membership promotional work carried out under the auspices of the Board of Directors' Membership Committee; and he will assist in other developmental activities including promoting an interest in many of the Society's publications.

The Society Appoints . . .

Announcement is made of the following appointments of Society representatives

F. N. ALQUIST, Dow Chemical Co., member of ASTM Committee D-19 on Industrial Water, as ASTM representative on the newly created Research Council on Causes and Methods of Prevention of Internal Corrosion of Water Pipes.

F. H. BAUMAN, New Jersey State Highway Department, on A.S.A. Sectional Committee A-37 on Road and Paving Materials, succeeding C. S. REEVE, deceased.

W. H. FINKELDEY, Singmaster & Breyer, reappointed as a member-at-large for a term of three years on the Advisory Committee on Corrosion.

A. H. SCOTT, National Bureau of Standards, succeeding C. T. HATCHER, on A.S.A. Sectional Committee C 59 on Electrical Insulating Materials.

L. H. WINKLER, Bethlehem Steel Co., Inc., and P. V. READER, National Supply Co., on A.S.A. Sectional Committee B 31 on Code for Pressure Piping, replacing C. L. KENT, Jones & Laughlin Steel Corp., and S. H. KILMER, National Supply Co. N. L. MOCHEL, Westinghouse Electric Corp., continues as a Society representative.

NECROLOGY . . .

The Death of the following members has been reported

JOHN J. BOWMAN, Metallurgist, Aluminum Company of America, Pittsburgh, Pa. (October 1, 1950). Personal member and representative of his company on various technical committees for many years. (See accompanying article.)

N. M. FINKBINER, Engineer of Materials, Oregon State Highway Commission, Salem, Ore. (September, 1950). Member since 1925.

HARRY T. NEWMAN, SR., Director of Central Testing Laboratory, Department of Purchase, New York City (March, 4, 1950). Representative of Department of Purchase membership since 1949. Born in Brooklyn and educated in the public schools and at Brooklyn Polytechnic Institute, Mr. Newman had been a City chemist for 41 years, rising through the ranks in the chemical service to Director of the Laboratory in 1946.

H. H. ROBERTSON, President, H. H. Robertson Co., Pittsburgh, Pa. (September 19, 1950). Member since 1912.

To the ASTM Committee on Membership, 1916 Race St., Philadelphia 5, Pa.

Gentlemen:

Please send information on membership to the company or individual indicated below:

_____

_____

This company (or individual) is interested in the following subjects: (indicate field of activity, that is, petroleum, steel, non-ferrous, etc.,)

_____

Signed _____

Date_____ Address_____

John J. Bowman
1907–1950

WHILE many of the friends and associates of John J. Bowman knew that he had a heart ailment, his apparent good health and disposition never gave any warning that the condition was so serious; hence his sudden death from a heart attack on October 1 came as a great shock. For many years he had taken a very active part in ASTM activities, particularly in the field of non-ferrous metals. In his connection as metallurgist with The Aluminum Company of America, he naturally focused his attention in ASTM work on light metals and alloys and die castings, but he had a considerably broader interest than this. For example, he was very active in the work of the ASTM Pittsburgh District, having served two terms as chairman and having been on the Council for many years. He had a notable record of service in Committee E-4 on Metallography where he was a very efficient secretary from 1936 to 1946. In Committee B-7 on Light Metals and Alloys he had been secretary since 1944, and served on numerous subcommittees and sections. In Committee B-6 on Die-Cast Metals and Alloys he was chairman of its Subcommittee on Aluminum-Base Die-Casting Alloys. He also served the Society as a member of the Administrative Committee on District Activities, and on the Coordinating Committee on Non-Ferrous Metals and Alloys.

After attending public schools in Millersburg, Pa., the family home, Mr. Bowman graduated from Pennsylvania State College in 1929 in electrochemical engineering. He joined the Aluminum Research Laboratories that year, and subsequently was appointed executive assistant to the chief metallurgist, and has been in his present position as a metallurgical executive since 1943 when he returned from work on the War Production Board in Washington in the Conservation Division. He was a member of several Pittsburgh groups and clubs. He is survived by his parents and a sister, all of Millersburg.

In his death ASTM loses one of its very active, relatively younger men who nevertheless had a notable record of service in its behalf. This brief record is intended to be a token of appreciation of these services and an expression of the loss which all those who knew Johnnie will feel.

LABORATORY SUPPLIES . . .

Catalogs and Literature and Notes on New or Improved Apparatus

Note—This information is based on literature and statements from apparatus manufacturers and laboratory supply houses.

Catalogues and Literature

Instruments and Accessories for Radio-Isotope Applications—A 44-page brochure featuring instruments and accessories for radio-isotope applications has been announced by the Scientific Instrument Manufacturers Assoc. of Great Britain, Ltd. It is intended to summarize the equipment available from British sources for isotope techniques in medicine, research, and industry.

Scientific Instrument Manufacturers Assoc. of Great Britain, Ltd., 17 Princes Gate, London S.W. 7, England.

Measurement of Radioactivity—A recently published bulletin gives full details on instruments and accessories for measurement of radioactivity. The bulletin illustrates a complete basic radiochemical laboratory, scalers, nucleometers, anthracene crystals, pipettes, absorbers, shields, carts, and protective clothing. 48 pages.

Bulletin 10, Radiation Counter Laboratories, Inc., 1844 W. 21st St., Chicago 8, Ill.

Laboratory Chemicals and Scientific Equipment—Referred to as Catalog No. 450, the catalog of the Burrell Corporation is an all-inclusive, up-to-date reference work on all kinds of laboratory apparatus and supplies. It lists over 25,000 items and includes many improved methods and aids for chemical analysis and testing. Four years of research and preparation have preceded its publication. An outstanding feature of Burrell's Catalog No. 450 is the convenient cross index system. Items are listed by name and again, separately, by function. For example: "furnaces" can be found on page 287 under the classification "Combustion (of steel)" and also on page 431 under "F" for furnaces. A complete description of each item accompanies every listing. The catalog serves also as a check on whether or not any particular item is obsolete. A survey was made item by item in the Burrell line to determine which items, if any, should no longer be offered. Obsolescence was determined on the basis of national sales figures for every product. The catalog contains 986 pages plus the index, weighs about 7 lb., and is bound in durable green leather.

Burrell Corporation, 2223 Fifth Avenue, Pittsburgh 19, Pa.

Toolmakers' Microscope—A completely new presentation is now available of this precision shop instrument two models of of which have not previously been described. Thirty features making the instrument valuable in toolrooms, gage laboratories, and inspection departments are itemized and dozens of new applications are indicated. 8 pages.

Bulletin 147-50, The Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago 14, Ill.

Organic Chemicals—The Matheson Company, Inc., presents price list No. 9 of its highly purified organic chemicals. This list contains several hundred new compounds which have been chosen because they seem to be of particular interest to the chemist. New compounds will be announced in future bulletins. 32 pages.

The Matheson Co., Inc., East Rutherford, N. J.

Instrument Notes

SR-4 Strain Recorder—A new strip chart strain recorder for continuous measurement of surface strain in structures or machines by means of SR-4 resistance wire strain gages is announced by The Baldwin Locomotive Works. The recorder is an electronic type instrument designed and calibrated for use with two SR-4 gages having a resistance of 120 ± 1.2 ohms and a sensitivity factor between 1.9 and 2.2. Usually one gage is active and the other is used for temperature compensation but both may be active for measuring combined bending and tensile stresses or differential strains. Available ranges in the instrument are 0–2000, 0–5000, and 0–10,000 microinches per inch. It provides ten chart speeds within a range of ¾ in. to 720 in. per hour or 12 in. per minute. The pen moves across a 4½-in. wide chart in a straight line, thus making coordinated readings of time *vs.* strain simple. Instruments are available with full-scale traverse speeds of one, three, or five seconds without overshoot. The pen may be zeroed at any point on the chart and the instrument range can be changed at any time during a measuring run if zero adjustment settings for all three ranges have been initially arranged.

The Baldwin Locomotive Works, Philadelphia 42, Pa.

Magnetic Mercury Cathode Apparatus—A 24-page bulletin presenting performance data, theoretical applications, actual procedures, extensive bibliography, operating instructions, and diagrams of construction of the Eberbach Dyna-Cath Magnetic Mercury Apparatus is available and may be obtained from the manufacturer.

Eberbach & Son Co., Ann Arbor, Mich.

Moisture Meter—A small moisture meter measuring 3½ by 4½ by 3½ in. overall case dimensions has been announced. The maker states the following as features of the instrument: weight less than 4 lb. complete with electrode holder, easy carrying with shoulder strap, requires only one common type battery and a single flashlight type cell to power it.

Henry A. Gardner Laboratory, Inc., 4723 Elm St., Bethesda 14, Md.

Laboratory Mill—A new laboratory mill designed for grinding from powder fine to coarse grind, features newly designed cutting plates, a large number of settings, and steel and leather wipers to continuously sweep the grinding chamber clean. The grinder is powered by a 1-hp motor and is built for continuous use. A smaller ½-hp version is also available.

Laboratory Construction Co., 1113 Holmes St., Kansas City, Mo.

Tumbler for Solids and Mixer for Liquids—A circular describing a tumbler for solids and a mixer for liquids is now available from Arthur S. LaPine & Co. According to the circular, the outstanding features of this mixer are: can be tilted through a 90° arc for complete

mixing at any angle; drive belt in constant tension regardless of load; will hold any size container, from 5-gallon cans to 1-ounce bottles; easily portable or can be bolted down if desired. Low price is also featured.

Arthur S. LaPine & Co., 121 W. Hubbard St., Chicago 10, Ill.

Microscope Illuminators—Recommended for illumination of transparent specimens, this new Micro-Lite is compact (only 8⅛ by 3⅛ in.), lightweight (just over 2 lb. including cord), and uses an ordinary 40-watt lamp. Louvers on the top and bottom permit flow of air around the lamp and keep the temperature comfortably cool. The ball and socket joint, pressure controlled, permits directing the light in any direction. The condensing lens is of the bull's-eye type with one surface ground to provide evenly diffused illumination. Above this lens is an antiglare shield protecting the user's eyes from stray light.

Bausch & Lomb Optical Co., Rochester 2, N. Y.

Portable 85-deg. Glossmeter—This new Glossmeter measures 85-deg. specular gloss according to Method 611.1, Federal Specification TT-P-141b. The instrument consists of an exposure head with lamp, lens, and sensitive light meter in essentially the arrangement employed in the new Gardner 60-deg. Portable Glossmeter. With this head is a power supply that may be either a transformer or a battery. This new unit has been designed especially for the measurement of sheen of interior wall paints and camouflage paints.

Henry A. Gardner Lab., Inc., 4723 Elm Street, Bethesda 14, Md.

Immersion Thermocouple—The molten steel thermocouple is a portable immersion type of novel design, as developed and licensed by the Republic Steel Corp., for the measurement of molten steel temperatures in the open hearth or electric arc melting furnace. Its construction is such that the accuracy is unaffected by variations in the surface emissivity of the steel, thus permitting the indication of the true metal temperatures. The thermocouple is suitable for intermittent service and will withstand immersion in the metal bath for the time necessary for temperature readings. Because of the high temperatures to be measured and the need for fast response, ceramic materials are used in that part of the thermocouple which is in direct contact with the metal bath.

Minneapolis-Honeywell Regulator Co., Industrial Div., Philadelphia 44, Pa.

Meter for Electrolysis, Corrosion and Cathodic-Protection Testing—A new model meter, called the B-3, for electrolysis, corrosion, and cathodic-protection testing, is now available. It is small, compact, and low priced compared to the previous model, although it has a low range of 2 millivolts and special mirror scales 3.9 in. long. The accuracy is 1 per cent. By use of a circuit selector switch, the two high sensitivity d-c. instruments can be connected into a variety of measuring circuits for measurement of potentials, current, resistance, and soil resistivity. Internal batteries with switch and coarse and fine controls can be used to supply and control current for test purposes. Voltmeters, or voltmeter and ammeter can be used separately or simultaneously. Polarity reversing switches are provided for both current and potential measurements.

M. C. Miller, 1142 Emerson Ave., West Englewood, N. J.

Electrometer for Low Currents—An electrometer for measuring currents as low as 10^{-15} amp., such as those produced in ionization chambers, is now available. Measurements are reduced by an electronic type chart potentiometer from signals detected and amplified by a sensitive preamplifier unit. 10^{-15} amp. (a billionth of a microampere) can be consistently recorded on a linear chart. The instrument combination can also function as an extremely high impedance millivoltmeter for measurements down to 10^{-4} volts.

Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pa.

Stretch Meter—An automatic recorder for determining the percentage of stretch or shrinkage of materials being processed is now offered by the Tagliabue Instruments Division of Weston Electrical Instrument Corp. The instrument is said to provide a continuous record of roll speed ratio for textile, paper, plastics, rubber, chemical, and metal-rolling industries. Operated by two tachometer generators, the new instrument consists essentially of a specially developed ratio recorder. It may be calibrated in per cent stretch, inches per yard shrinkage, or other units which are a function of the speed ratio between the two rotating Weston members.

Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N. J.

Beaker Holder—A new beaker holder designed to eliminate accidents caused by hot or corrosive liquids is announced. Made of stainless steel with insulating fiber handles the need for gloves or the corner of an apron is said to be eliminated. Rigidity of the holder permits attachment to a ring stand and minimizes vibration during stirring.

Will Corporation, Rochester 4, N. Y.

INSTRUMENT COMPANY NEWS . . . .

Announcements, changes in personnel, new plants and locations, and other notes of interest

Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N. Y., announces the appointment of Capt. Alf O. Bergesen, USN (ret.) as administrative assistant to the head of the Military Engineering Department. Capt. Bergesen, who was U. S. Naval attache at Oslo, Norway, from 1945 to 1947, was in charge of the Navy's NROTC program at the University of Rochester until his retirement last month.

Fisher Scientific Co., 717 Forbes St., Pittsburgh, Pa., has purchased from the Weston Electrical Instrument Corp. the patent rights, manufacturing tools and dies, and inventory of one of the most respected lines of petroleum testing equipment in the country—The Tag line founded by C. J. Tagliabue. Henceforth, this line of petroleum testing instruments will be manufactured in the Pittsburgh shops of the Fisher Scientific Co. and will be distributed through the five Fisher and Eimer & Amend plants and through authorized dealers under the registered trade name of Fisher-Tag. This basic line of testing equipment includes many instruments manufactured in accordance with the American Society for Testing Materials specifications. Included in the Fisher-Tag line are colorimeters, chromometers, viscosimeters, cloud and pour test apparatus, Pensky-Martens Flash Point Testers, Cleveland Open Cup Flash Testers, and many other instruments made expressly for petroleum testing. It is also of interest that the Fisher Scientific Co. has constructed a new and extensive plant in Washington, D. C. It was scheduled for completion by October 15, 1950. One of the main reasons for the new plant was to establish a complete stock of laboratory supplies. It is stated that all of the items listed in the Fisher Catalog 90 will be stocked in the new plant. Additional information on the purchase by Fisher of the Tag petroleum line and also the new Fisher plant in Washington, D. C., may be had by consulting the Fisher house organ *Laboratory*, Volume 20, No. 1.

Arthur S. LaPine & Co., 121 W. Hubbard St., Chicago 10, Ill., announces the promotion of Charles A. Rossiter, who will now be in full charge of sales with his company. His title will be Sales Manager.

National Technical Laboratories, 1114 First Ave., New York, N. Y., manufacturers of the well-known Beckman pH meters, spectrophotometers, and other scientific instruments has announced that it has changed its corporate name to Beckman Instruments, Inc. The change was made in order to more closely identify the company as the developer and manufacturer of Beckman instruments and accessory equipment.

E. H. Sargent & Co. announces a new city service department at 4647 W. Foster Ave. in Chicago. The department contains a convenient parking arrangement and may be reached easily by bus.

The Will Corporation, distributor of laboratory equipment and supplies, has acquired its fifth division, with the purchase of the business of E. J. Callahan & Co., of Baltimore, Md., and will operate it under the corporate name of Will Corporation of Md. The announcement comes from H. J. Coleman, president of Will. The Baltimore acquisition was made in order to offer faster and more complete service to Will's customers in Maryland, Delaware, and the District of Columbia. E. J. Callahan, former owner of the Baltimore concern, has been named a Vice-President of the Will Corporation. Joseph H. Dunn, formerly associated with Will in Rochester and Buffalo, will operate the Baltimore Division for Will.

BOOK REVIEWS...

Exudation and Allied Reactions Between Bitumens

Stress Analysis Handbook

A UNIFIED presentation of theory and all experimental methods for the determination of mechanical strength is made in "Handbook of Experimental Stress Analysis." Written by 31 qualified stress analysts, under chief-editorship of M. Hetenyi, the included material should be of value to machine designers, structural designers, ship designers, aeronautical engineers, instrument designers, and students in these fields.

There are chapters on mechanical properties, testing machines and gages, optical methods of strain measurement, electrical resistance gages and theory, inductance gages and capacitance gages, motion measurements, strain rosettes, working stresses and residual stresses, methods of crack detection, interpretation of service fractures, brittle models and brittle coatings, structural model and dimensional analyses, photoelasticity, and X-ray analysis.

Appendices are on fundamental theory, and the precision of measurement.

The handbook is profusely illustrated with curves, diagrams, tables, and photographs.

The "Handbook of Experimental Stress Analysis" is published by John Wiley and Sons, Inc., New York, N. Y., and sells for $15.

Modern Refractory Practice

IN THE third edition of Modern Refractory Practice, recently off press, the Harbison-Walker Refractories Co. has done a splendid job in presenting a very comprehensive and interesting coverage of various factors dealing with refractory materials and products. The makeup of the book itself is of high quality and appearance with a generous use of illustrations and photographs which help so much in making such a text interesting to read.

In its preparation, special effort has been made to include such engineering and technological data as will be most useful to those interested in refractories and their applications. Included in the book are chapters covering the several types of refractories such as industrial, fire clay, high-alumina, silica and basic, with reference made to the many products of the company for these particular uses. Insulating and acid-proof refractory products are also described with much valuable information furnished covering properties and factors entering into their use. Complete data are available in the form of tables and illustrations on standard sizes and modified shapes. Valuable knowledge is furnished in chapters on the selection and use of refractories and on properties. Reference is made to the Manual of ASTM Standards on Refractory Materials in prescribing the standard methods for determining these properties. General information includes technical data such as conversion factors and melting points and also formulas and tables useful in calculating brickwork. A rather complete glossary of terms used in the refractory industry is contained in the closing chapter of this very informative text.

The 400-page Modern Refractory Practice is offered without charge to users of refractories, to libraries, and to heads of departments in universities and technical schools. For general distribution or for student use, a charge is made which is much lower than the cost of preparation.

Sampling and Testing Ready-Mixed Concrete

THE Engineering Division of the National Ready-Mixed Concrete Association has published a booklet outlining recommended practices for sampling and testing ready-mixed concrete based on the ASTM Standard Specifications for Ready-Mixed Concrete (C 94) and the methods of sampling and testing referred to in this specification.

Ready-mixed concrete, for the most part, is sold on the basis of specified properties—proportions, cement factor, consistency, strain, etc. The values found for these properties not only determine the acceptance of the concrete but also greatly affect the reputation of the producer. It is of utmost importance, therefore, that standard procedures based on experience and found to be reliable be used, from securing the sample through all phases of determining and reporting test results. These recommended practices have for a principal purpose summarizing and interpreting ASTM standards of particular interest to the ready-mixed concrete industry. A secondary purpose is to supplement them in the light of experiences of representative producers and testing engineers. The testing methods referred to in the booklet deal with tests of the mixed concrete only. In addition to the ASTM methods described in the booklet, there is a list of allied ASTM standards.

The booklet was prepared by a special committee of the association. The chairman of the committee was Julius Warner, and editorial work and coordination was done by Fred F. Bartel and Stanton Walker.

New Portuguese Publication on Cork

"CORTICA APPLICADA," by Almeida Garrett, (written in Portuguese) is an earnest attempt to bring to cork technologists all the available information on Portuguese industrial cork. Three sections of the book cover Raw Materials and Products, Thermal, Acoustic, and Vibration Insulation, and Problems in the Use and Manufacture of Cork. A rather extensive bibliography contains references, about 60 per cent of which are American. Further information can be obtained by writing to Almeida Garrett, c/o Livraria Ferin, L.Da, 70 Rua Nova do Almada, 74 Lisboa, Portugal.

Paper Making—T.A.P.P.I.

A "1949 Bibliography of Paper Making, Uses and Patents" compiled by Clarence J. West, Chairman of the Bibliography Committee, T.A.P.P.I., and Research Associate and Editor of The Institute of Paper Chemistry, Appleton, Wis., contains the literature on pulp and paper manufacture published recently, and also the patents issued which are of interest to the pulp and paper industry. A list of the journals covered, the actual bibliography, abstracts of the patents, author index, the subject index, and the patent index are included in the 285-page bibliography. Further information can be obtained by writing to Mr. West, The Inst. of Paper Chemistry, Appleton, Wis.

Toward Wiser Use of Wood

A VERY interesting booklet has been prepared and published by, and at the expense of, the employees of the U. S. Forest Products Laboratory. The booklet has been written to commemorate the first 40 years of service rendered by the Laboratory and its employees and describes in a very interesting manner the history of forest conservation and the efforts made to establish this laboratory which is now considered to be one of the best of its kind in the field of forest products. It is written in a very informal style making it easy to read and contains several excellent illustrations made from wood engravings. A limited supply of copies of this booklet are available through contact with the Forest Products Laboratory Employees Association, Madison, Wis.

Some Recent Books....

Motor Oils and Engine Lubrication. Carl W. Georgi, Quaker State Oil Refining Corp., Buffalo, N. Y. 515 pages. Reinhold Publishing Corp., 330 West Forty-second St., N. Y. $8.50.

Out of My Later Years. Albert Einstein. 276 pages. Philosophical Library Inc., 15 East 40th St., New York 16, N. Y. $4.75.

Phenomena, Atoms and Molecules. Irving Langmuir. 400 pages. Philosophical Library, Inc., 15 East 40th St., New York 16, N. Y.

Pocket Encyclopedia of Atomic Energy. Frank Gaynor, editor. 200 pages. Philosophical Library, Inc., 15 East 40th St., New York 16, N. Y. $7.50.

Primary Batteries. George Wood Vinal, Sc.D., Physicist, National Bureau of Standards. 329 pages. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. $5.

Welding Handbook. 3rd Ed. Welding Handbook Committee. 1579 pages. American Welding Society, 33 West 39th St., New York 18, N. Y. $12.

Fortschritte und Forschungen im Bauwesen (Magazine). Franckh'sche Verlagshandlung W. Keller & Co., Stuttgart-O, Pfizerstrasse 5-7, Germany. A current issue (Reihe C, Heft 1) contains what may be a rather significant paper on water vapor condensation and permeability in building materials ("Feuchtigkeitsdurchgang und Wasserdampfkondensation in Bauten," K. Egner.)

Evaluation of Rubbing Compounds for Use on Lacquered Aircraft Surfaces[1]

By Roy A. Machlowitz[2]

SYNOPSIS

The work reported in this paper was performed as a basis for a specification covering procurement of rubbing compounds for use on the lacquered surfaces of naval aircraft. The procedure followed in preparing the specification, including a questionnaire survey of the aircraft industry, is discussed in detail. The following properties of rubbing compounds were determined: caking number, low-temperature stability, freezing point, flash point, chemical attack, corrosiveness, pH, and rubbing efficiency. Results of tests of 21 rubbing compounds are given. A possible use of the rubbing efficiency test procedure to determine the speed of through dry of lacquers to the point of being ready to be rubbed is outlined.

THE DEVELOPMENT of aircraft having speeds in the trans-sonic range has focused attention on the problem of obtaining aerodynamically smooth surfaces to minimize speed-reducing drag and turbulence. Since the corrosive conditions encountered by naval aircraft aboard aircraft carriers at sea necessitate that such planes be painted, extremely smooth painted surfaces must be obtained without the use of weight-increasing multiple coats of paint. To insure proper application of the standard aircraft finishes, all painting procedures are performed in accordance with a carefully devised specification, Bureau of Aeronautics Specification SR-156a.[3] To attain the smoothest possible paint film, SR-156a requires that the dried film, usually a nitrocellulose lacquer, be sanded with Wetordry sandpaper, followed by the use of a rubbing compound to remove the sanding pattern, "orange peel," dried overspray, dust particles, etc. While a large number of rubbing compounds are commercially available, naval procurement policy dictates that purchases of materials be restricted to those products which comply with specifications. Accordingly, the work reported in this paper was performed as a basis for a specification covering rubbing compounds. The specification was subsequently issued as Bureau of Aeronautics Specification 52R17(Aer.)[4]

Information as to the eventual use of the product covered, in terms of mode of application, product requirements, and performance desired, is essential for the preparation of such a specification. The following questionnaire was therefore prepared and sent to 15 leading aircraft manufacturers:

Text of Questionaire:

"1. Do you use a rubbing compound as a final smoothing agent or to remove orange peel, lumps, etc., in the lacquer coats?

"2. Do you apply the rubbing compound by machine over most of the plane, using a hand rubbing material only in areas inaccessible to a buffing machine or do you use a hand rubbing compound more generally?

"3. Do you use Wetordry sandpaper in your finishing procedure?

"4. How many man-hours are expended in using a rubbing compound on a plane?

"5. Approximately how many strokes, in the case of a hand rubbing compound, or revolutions, in the case of a machine rubbing compound, are used per square foot of surface?

"6. How did you select or evaluate the rubbing compound employed in your finishing procedure?

"7. What rubbing compounds have you found particularly effective?

"8. Do you prefer to have the wax incorporated in the rubbing compound or is a separate wax preferred?"

The replies to the questionnaire indicated that certain general practices prevailed in the aircraft manufacturers' use of rubbing compounds. All used Wetordry sandpaper prior to the application of rubbing compounds. All preferred a separate wax to one incorporated in the compound. The estimates of the number of man-hours required per plane varied from 16 to 50. Question 5 elicited a wide range of replies, with the estimated number of hand strokes used per square foot ranging from 15 to 50. The estimates of the number of revolutions of a power-operated buffing wheel required per square foot of surface varied from 75 to 1500. Most companies based their selection of the compound used on shop personnel preference, only one reporting even simple laboratory evaluation. Eight different rubbing compounds were mentioned, with four manufacturers naming one, Sample M in this report. This material was, however, used for both hand and buffing wheel application by different manufacturers. Two manufacturers stated objections to power-driven buffer application of rubbing compounds. One objection was the removal of paint from rivet heads. The other was that the rapidly revolving disk scattered the compound, interfering with nearby workers. These two manufacturers reported that hand application of rubbing compounds was more rapid and efficient than machine application.

Upon completion of the questionnaire study, all the major manufacturers of rubbing compounds listed in Thomas' Register, in addition to those named in the replies to the questionnaire, were requested to submit samples for the laboratory test program. A total of 21 samples was received and used throughout this work.

The test methods and specification requirements which were developed are divisible into four categories, under which they will be discussed in some detail.

Safety of Personnel Using Rubbing Compounds:

Provisions for the safety of personnel were made in the specification resulting from this work by including a general prohibition of materials constituting a medical hazard or producing obnoxious vapors. This was supplemented by a specific prohibition of the use of chlorinated hydrocarbons with the exception of dichloromethane. Trichlorethylene and perchlorethylene were permitted in low concentrations only.

Storage and Shipment Qualities:

The wide range of conditions under which materials are stored and shipped throughout the complex naval supply

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NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] The opinions expressed in this paper are those of the author and not necessarily official opinions of the Naval Air Experimental Station or the Navy Department.

[2] Chemist, Aeronautical Materials Laboratory, Naval Air Experimental Station, Naval Air Material Center, Naval Base, Philadelphia, Pa.

[3] Bureau of Aeronautics Specification SR-156a —Finishes; Aircraft, Application and Treatment for Producing Aerodynamically Smooth Surfaces, dated January 3, 1949.

[4] Bureau of Aeronautics Specification 52R17 (Aer), Amendment-1—Rubbing Compound (for Lacquered Surfaces), dated September 12, 1949.

organization necessitates that specifications contain provisions designed to eliminate those products likely to deteriorate in storage. The following tests were included, though some of them have not been correlated with field use:

Caking Number Test (for liquid samples only).—Duplicate 50-ml. samples of the compound in Fisher Scientific Co. No. 5-565 tubes were centrifuged for one minute at 500 rpm. The number of gentle inversions then required to loosen the cake of abrasive which formed in the tube was noted, with a maximum of 20 being permitted. The deficiencies of this test have been cited elsewhere.[5]

Low Temperature Stability Test.—To insure the stability of the rubbing compounds when stored at low temperatures, duplicate samples of compound were subjected to three 2-hr. periods at -40 ± 4 F. with 1-hr. periods at 117 ± 2 F. intervening. Five minutes of gradual warming from -40 F. to 117 F. were used to prevent the temperature cycle from being too severe on the materials under test or the glassware used in the test. After thawing at room temperature for 16 hr., an acceptable material must be restorable to its original appearance by vigorous manual shaking.

Freezing Point (for liquid samples only).—As an additional assurance of usability at low temperatures, a procedure similar to the Federal Specification VV-L-791 Method 20.16 "Cloud and Pour Point" determination was used except that the sample is not preheated and the point of cessation of movement is called the freezing point rather than the pour point. The compound is not considered acceptable if it freezes above 0 C. (32 F.).

Flash Point.—Federal Specification VV-L-791 Method 110.24 (A.S.T.M. D 93–42) entitled "Flash Point by Means of the Pensky-Martens Closed Tester" was used to determine the flash point with the minimum acceptable value being 60 C. (140 F.). The use of a closed cup tester rather than an open cup tester merits some discussion, since it was known that none of the rubbing compounds tested contained any low-flash solvents. It was found that the values obtained using an open cup tester were as much as 20 C. below the flash point of the ingredient having the lowest flash point. This anomaly may be understood when the nature of the materials being tested is considered. Rubbing compounds contain large percentages of abrasives. These siliceous materials were forming an insulating shield around the centrally located thermometer so that the registered temperature was far below the actual temperature of the solvents which were being ignited, since open cup methods do not permit stirring of the sample during a determination. This difficulty was eliminated by the use of the Pensky-Martens tester, which has a built-in stirring device rather than either the open cup or the Tag closed cup.

[5] Roy A. Machlowitz, "Evaluation of Polishes for Use on Aluminum Aircraft Surfaces," ASTM BULLETIN, No. 156, January, 1949, p. 46.

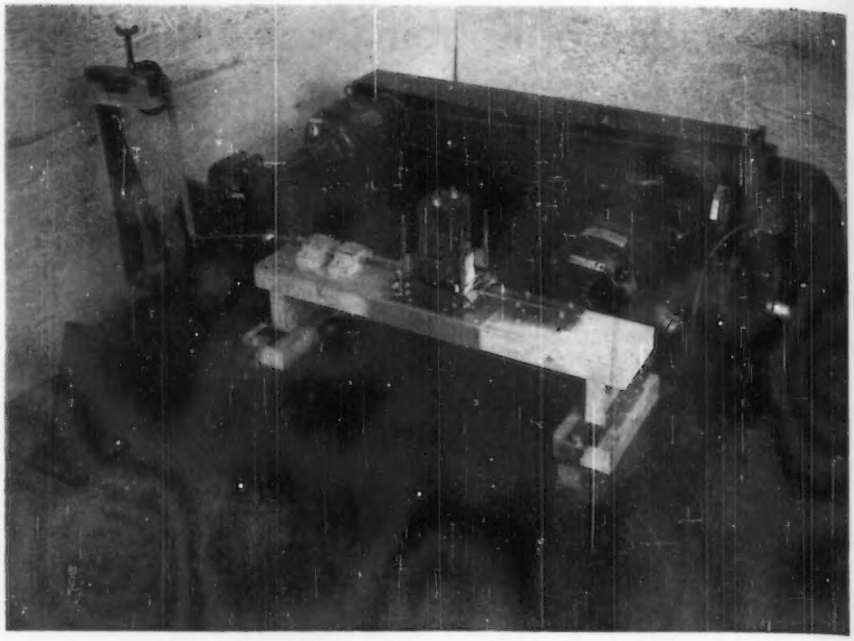

Fig. 1.—Over-All View of Rubbing Efficiency Test Set-up.

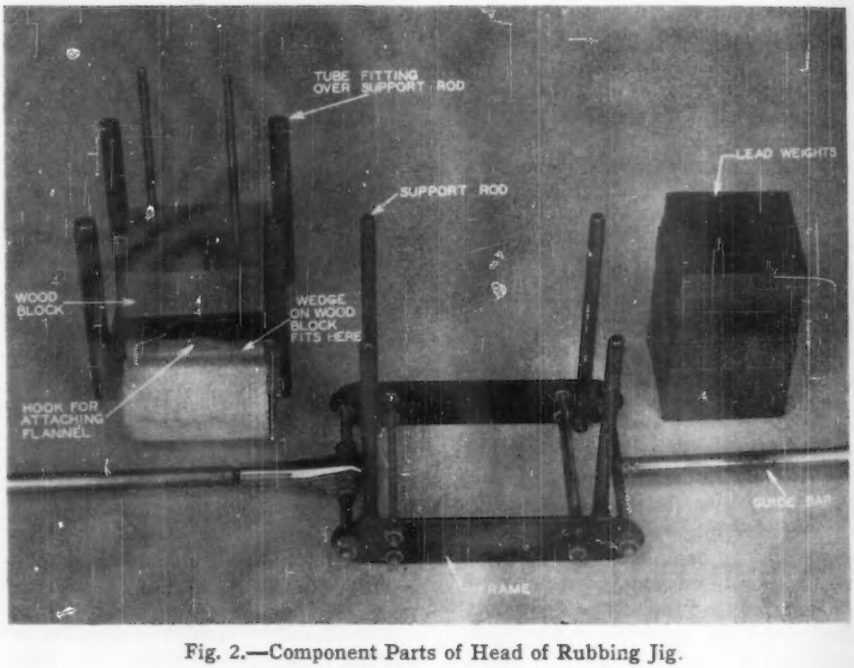

Fig. 2.—Component Parts of Head of Rubbing Jig.

Effect on Aircraft Materials:

The following tests were conducted to determine whether the rubbing compounds would have any deleterious effect on lacquered surfaces or the metal most commonly employed in fabricating aircraft.

Chemical Attack.—Duplicate test panels were prepared by coating aluminum panels with one coat of AN-P-656 zinc chromate primer and two coats of AN-L-29 insignia white lacquer, in accordance with standard practice. After drying, the panels were covered with rubbing compound and kept at room temperature for 24 hr., after which the lower halves were wiped clean, using a soft cloth, and the paint film examined for evidence of attack. Twenty-four hours later, the upper halves were also wiped clean and the paint film examined.

No evidence of chemical attack, such as pitting or discoloration, is permitted.

Corrosiveness.—Duplicate aluminum-clad aluminum alloy panels, Specification AN-A-13, were coated with rubbing compound and kept at room temperature for 24 hr., after which the lower halves were wiped clean, using a soft cloth and the panels examined for evidence of corrosion. After an additional 24 hr., the upper halves were also wiped clean. No corrosive attack, discoloration, or more than slight staining is permitted.

pH Determination.—A 10 ±0.5-g. sample of the rubbing compound was stirred with 75 ml. of freshly boiled and cooled distilled water and then the pH was measured electrometrically. A value of 10.7 or less is required.

Rubbing Efficiency Test:

The tests described thus far have been concerned with possible deterioration in storage or deleterious effects on aircraft materials. The performance properties of the rubbing compounds were determined by the rubbing efficiency test. A satisfactory performance test must meet the following criteria: (1) no variable human element should be present; (2) the forces involved in the test should be similar to those employed in actual use; (3) the test panels must be uniform; and (4) evaluation of the test results should be objective and simple.

The first criterion was met by the design and development of the test apparatus shown in Figs. 1 and 2. The test machine has a power-driven reciprocating polishing head operating under a load which may be varied. There is a counter to record the number of strokes used. The polishing head is cradled on the graphite-lubricated support rods of the guided metal frame. This apparatus moves the rubbing head in a level path in an undeviating, back-and-forth motion. The test load is borne equally over the entire rubbing surface. The test conditions may be altered very easily when desired.

Meeting the second criterion was somewhat more difficult since the forces to be duplicated are subject to considerable variation. In production, rubbing compounds are generally used manually on aircraft surfaces by shop personnel who work at the job with human variation in the intensity of effort expended. No exact way is available of mechanically duplicating the average force applied under such conditions. To get an approximation of the forces involved, five workers each rubbed a large painted panel resting on the platform of a 0 to 50-lb. scale for 10 min. while an observer noted the loads recorded on the scale dial. (This procedure was much simpler than the more accurate procedure of using a section of a wing instrumented with strain gages and was considered sufficiently indicative for the purpose.) It was found that light rubbing registered about 8 lb. The average rubbing force was 15 lb. while 20- to 25-lb. rubbing could be maintained for only brief intervals. The 8- and 15-lb. loads were selected as constituting minimum and average conditions with the number of strokes serving as the variable limiting the severity of rubbing. Preliminary tests showed that lacquered panels rubbed with 100 strokes under 8-lb. load and 40 strokes at 15-lb. load developed "good looking" surfaces. The former test condition constituted minimum acceptable usability while the latter more severe condition served to eliminate compounds containing coarse abrasive particles likely to produce excessive gouging under the increased load.

Preliminary tests showed poor reproducibility of results which was traced to variations in the routinely prepared test panels being used. The undesirable variations were the result of the panels not having level surfaces and of variations in paint application. The use of machined level 3 by 5 by 0.125-in. S.A.E. 1025 steel panels eliminated the difficulty inherent in the previously used thin gage metal sheet stock. The use of an automatic spraying machine (a rather simple mechanical device which moved a rigidly mounted spray gun over a definite path at a pre-determined rate) eliminated variations in paint application. The use of set values for line pressure, fluid nozzle opening, distance from spray gun to panel, and rate of gun travel resulted in the preparation of sets of panels by different operators in which the maximum variation in paint film thickness was less than 0.0001 in., as measured by the Magnegage. The line pressure and fluid nozzle opening used were deliberately chosen to produce an "orange peel" surface so that the smoothing effect of the compound under test could be evaluated. ("Orange peel" is the term commonly used to describe a pimply paint film having the texture of the skin of an orange.) One coat of AN-P-656 zinc chromate primer and two coats of AN-L-29 aircraft gray lacquer were used as specified in Bureau of Aeronautics Specifications 156a. Control batches of primer and lacquer were set aside to eliminate variation in the paint materials used.

When used under field conditions the degree of smoothness resulting from the use of a rubbing compound is a function of the compound used and the judgment of a skilled workman. This latter criterion cannot, of course, be used in test work. The smoothness produced by using a rubbing compound under test conditions may be measured in a variety of ways including the use of a Brush analyzer or pressure drop of a stream of air flowing over the panel. These were considered too complex, however, for use in a specification so that the loss in weight as a result of the rubbing test coupled with visual examination was chosen as a simple, direct means of measuring the compound's rubbing efficiency.

A detailed description of the rubbing efficiency test included in the specification follows:

Rubbing Block.—The rubbing surface of the block shall be 4 by 3 in. and designed so that a strip of flannel may be securely clamped to and stretched taut over the block in order to completely cover the bottom rubbing area. Provision shall be made for the attachment of lead weights to the top of the block in an evenly apportioned manner to give total weights of 8 and 15 lb. The block shall be operated in a level, smooth, reciprocating motion through a distance of 2 in. in a direction parallel to the length of the block. The block shall operate at a speed of 40 strokes per min., a stroke being considered as one complete cycle from starting position of block and return to starting position.

Panels.—Steel panels 3 by 5 by 0.125 in., conforming to Specification AN-S-11, one face of which shall be machined level, shall have the level face coated with one coat of zinc chromate primer, Specification AN-P-656, and two coats of aircraft gray lacquer, color number 512, Specification AN-L-29, in such a manner that the total thickness of the dry coats is 1.6 ±0.1 mil. (0.0016 ±0.0001 in.). After air-drying for 10 days the panels shall be washed vigorously with mild soap solution to remove loosely adhering paint particles on the edges, rinsed, and dried thoroughly and weighed to the nearest milligram.

Procedure.—A weighed panel, prepared as specified above, shall be held securely in position beneath the rubbing block with the 5-in. dimension parallel to the length of the block. A fresh strip of flannel, Specification CCC-F-466, Type I, shall be clamped on the rubbing block. Weights shall be added to a tota rubbing block weight of 8 lb. Two milliliters of the rubbing compound shall be measured by means of a calibrated plunger assembly, care being taken to eliminate air pockets. The rubbing compound shall be spread, using a spatula, as evenly as possible over the portion of the flannel which will contact the panel. The rubbing block shall be placed in position and moved through 100 strokes. This shall be repeated

TABLE I.—RESULTS OF TESTS OF 21 RUBBING COMPOUNDS.

Rubbing Compound Sample	Toxicity	Caking Number (Liquids Only)	Low-Temperature Stability	Freezing Point (Liquids Only), deg. Fahr. (deg. Cent.)	Flash Point, deg. Fahr. (deg. Cent.)	Chemical Attack of Lacquered Surface	Corrosive Attack on Alclad Surface	pH	Rubbing Efficiency Test—Weight Loss, mg.		
									100 Strokes, 8-lb. Load	40 Strokes, 15-lb. Load	Sum of Losses from Both Tests
Buaer Specification 52R17(ALER) Requirement	Non-toxic	20 max.	Readily restorable to original condition	32 (0) max.	140 (60) min.	No attack	No attack	10.7 max.	..	..	..
A	OK	.....	OK	.....	148 (65)	Slight discoloration—acceptable	Slight discoloration—acceptable	9.5	4	10	14
B	OK	.....	OK	.....	146 (63)	No attack	No attack	9.6	9	7	16
C	OK	.....	OK	.....	160 (71)	No attack	No attack	10.4	7	9	16
D	OK	.....	OK	.....	142 (61)	No attack	No attack	10.3	8	10	18
E	OK	.....	OK	.....	170 (77)	No attack	No attack	10.3	10	11	21
F	OK	.....	OK	.....	158 (70)	No attack	No attack	10.4	10	15	25
G	OK	Less than 20—exact number could not be determined[b]	OK	57 (14)[a]	148 (65)	No attack	No attack	9.5	14	15	29
H	OK	.....	OK	.....	148 (65)	No attack	No attack	10.4	12	19	31
I	OK	.....	OK	.....	184 (65)	Slight discoloration—acceptable	Slight discoloration—acceptable	10.0	17	15	32
J	OK	.....	OK	.....	144 (62)	No attack	No attack	9.8	17	15	32
K	OK	.....	OK	.....	148 (65)	No attack	Slight discoloration—acceptable	9.8	16	16	32
L	OK	.....	OK	.....	158 (70)	No attack	No attack	7.2	20	14	34
M	OK	.....	OK	.....	150 (66)	No attack	No attack	10.2	19	20	39
N	OK	6	OK	30 (−1)	152 (67)	No attack	No attack	9.3	20	26	46
O	OK	.....	OK	.....	158 (70)	No attack	Slight discoloration—acceptable	10.2	21	26	47
P	OK	.....	OK	.....	134 (57)[a]	No attack	No attack	10.0	22	27	49
Q	OK	.....	OK	.....	158 (70)	No attack	No attack	9.8	26	26	52
R	OK	.....	OK	.....	162 (72)	No attack	Slight discoloration—acceptable	9.8	24	30	54
S	OK	.....	OK	.....	152 (67)	Slight discoloration—acceptable	No attack	8.6	35	30	65
T	OK	.....	OK	.....	160 (71)	No attack	No attack	7.6	32	38	70
U	OK	.....	OK	.....	148 (65)	No attack	No attack	9.9	32	39	71

[a] Does not comply with specification requirement.
[b] The disappearance of the cake at the bottom of the tube could not be observed. After 20 inversions, the tube was emptied and no cake was present.

with a second panel, using fresh flannel and rubbing compound. The entire procedure shall be repeated, using a total rubbing block weight of 15 lb. and only 40 strokes. A duplicate panel shall be tested in this instance also, using fresh flannel and compound.

Results.—After completion of the rubbing procedure, the rubbing block shall be lifted and the flannel discarded. The panels shall be washed thoroughly, using a mild soap solution and a soft cloth. Each panel shall be dried thoroughly and weighed. The loss in weight of each panel shall be calculated. The panels shall also be examined visually for smoothness and evidence of excessive rubbing.

Duplicate determinations at each of the rubbing efficiency test conditions proved to differ by 3 mg. or less, which is considered satisfactory reproducibility for a test of this type.

Results of Tests:

The results obtained on all 21 samples subjected to the tests described in this paper are shown in Table I. The requirements of Bureau of Aeronautics Specification 52R17(Aer), where applicable, are stated at the top of each column. It will be noted that a rather wide range exists among the 21 samples in each of the properties reported numerically, that is, flash point from 134 F. (57 C.) to 170 F. (77 C.), pH from 7.2 to 10.4 and sum of weight losses in the rubbing efficiency test from 14 to 71 mg. Since all rubbing compounds are essentially alike in consisting of abrasives suspended in an oil-in-water emulsion, the data reflect variations in the ingredients used—solvent, emulsifier and hardness and coarseness of the abrasives. In view of the existence of a service need for three different types of rubbing compounds, namely, those which are best used by hand, those which are best for use with power-operated buffing wheels, and those which may be used either way, the results of the rubbing efficiency test were used to establish these three categories. Bureau of Aeronautics Specification 52R17 (Aer) limits the machine-use-only type to those compounds producing a sum of the losses under the two test conditions of 10 to 23 mg., hand-or-machine-use type 24 to 43 mg., and hand-use-only type 44 to 75 mg. Sample M, mentioned previously as being widely used in the aircraft industry, is an example of the intermediate category.

An interesting side observation on the rubbing efficiency test is that by a simple reversal of the two major variables involved, the lacquer and the rubbing compound, the test has possibilities of use as a measure of the speed

of lacquer dry to the point of being ready for rubbing. This point is of considerable interest to those who use lacquer in production line operations, notably the automobile industry, which require fast drying lacquers so as to avoid long delays prior to application of rubbing compound. While this test has not been conducted in this manner at the author's laboratory, the following procedure would seem suitable: a group of primed panels would be sprayed with the lacquers to be tested under standard conditions in an identical manner and tested at appropriate drying intervals, for example, 30 min., 60 min., 90 min., in the rubbing efficiency test procedure using one rubbing compound, previously selected as the one to be used in production. The weight losses produced at the various drying intervals would be a measure of the lacquers' speed in drying to the point of being ready to be rubbed. This method should also, when suitably modified, be applicable to other paint materials. The suggested test procedure might also be used in studying the effect of variations in lacquer thinner composition on the speed of lacquer drying to the point of being ready for rubbing.

Conclusions:

The procedures discussed herein were devised and utilized to prepare a specification constituting an objective mean of evaluating rubbing compounds in terms of their eventual use. The specification provides a basis for equitable competitive procurement without unduly restricting manufacturers' ingenuity, which might be the case with a rigid formulation-type specification. It is believed that the principal test of the specification, the rubbing efficiency test, provides a relatively simple method of determining the usability of rubbing compounds. This test may possibly be adapted to serve as a test of the speed of dry of lacquers to the point of being ready to be rubbed.

Compressor Lubrication[1]

By K. L. Hollister[2]

RIGHT after the war, a comprehensive study of compressor lubrication was made, particularly from the standpoint of evaluating the newer type oils as compressor lubricants. In making this study, first, the properties of the various oils were determined in The Texas Company Laboratories, Beacon, N. Y., second, the requirements of different type compressors were examined, and, third, the best oil for each type compressor was selected. Since that time, for the past several years, results of this investigation have been applied commercially with considerable success.

As a basis for the evaluation of the newer type lubricants, five commercial oils were chosen, all having a viscosity of approximately 300 Saybolt Universal sec. at 100 F. These five oils were:

1. A straight naphthene oil.
2. The same naphthene oil inhibited against rust and oxidation.
3. The same naphthene oil compounded with 3 per cent fatty oil.
4. A detergent heavy-duty oil.
5. A straight paraffin-base oil.

TABLE I.—IDENTIFICATION TESTS.

Oils	A.P.I. Gravity, ASTM D 287	Saponification Number, ASTM D 94	Ash, per cent, ASTM D 482
Inhibited naphthene	23.1	0.03	0.00
Straight naphthene	23.1	0.03	0.00
Compounded naphthene	23.3	6.50	0.01
Detergent paraffin	27.5	1.60	0.24
Straight paraffin	29.3	0.03	0.00

The physical tests on these oils are shown in Table I.

Having selected the five oils, they were next subjected to a gamut of physical and chemical tests designed to measure characteristics of interest from the standpoint of compressor lubrication. The first consideration was of course the most important function of a lubricant, namely, to reduce friction and prevent wear. The factors which are of interest in this connection are viscosity, evaporation, film strength, and water reaction.

It will be noted from Table II that, as would be expected, since all oils have the same viscosity at 100 F., the naphthene oils are less viscous at 210 F. Calculations show, however, using the ZN/P formula applied to a conventional compressor that the difference in viscosity at 210 F. between the oils is not sufficient to affect appreciably the coefficient of friction or the film thickness.

The rate of evaporation of the various oils at 250 F. is also shown in Table II and while there is a difference between the oils, even in the case of the most volatile oil, in an average compressor the evaporation is less than 5 per cent of the total oil consumed. In other words, over 95 per cent of the oil is removed from the cylinder walls by mechanical action, and any difference in the evaporation characteristics of the oils is of no concern at the comparatively low cylinder wall temperature.

The film-strength values as measured on the Almen machine are also given in Table II. The compounded oil will give slightly more protection against scuffing while the detergent oil is considerably better in this respect. In a compressor, however, most wear is due to contamination against which extreme pressure agents offer no protection and, therefore, only in rare cases will a high film strength oil be needed.

Water affects the lubrication of an air compressor in two ways. If it condenses on the cylinder walls it will interfere with lubrication and cause wear. If it is present in any portion of the system, rusting may occur. Rusting in a compressed air system cannot be tolerated

TABLE II.—WEAR FACTORS.

Oils	Viscosity Saybolt Universal sec. at 210 F., ASTM D 88	Evaporation, oz. per sq. ft. per hr. at 250 F.	Almen Value, psi.
Inhibited naphthene	48	0.020	4 000
Straight naphthene	48	0.016	4 000
Compounded naphthene	48	0.020	5 000
Detergent paraffin	54	0.006	10 000
Straight paraffin	54	0.003	4 000

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Paper presented before the American Society of Lubrication Engineers on January 25, 1950, and before Section U-VI, Technical Committee B of ASTM Committee D-2 on Petroleum Products and Lubricants on February 21, 1950, at Washington, D. C.

[2] Technical and Research Division, The Texas Company, New York, N. Y.

TABLE III.—WATER REACTION.

Oils	Antirust Rating, ASTM D 665	Humidity Cabinet Rating, AN-H-31	Emulsifying Tendency
Inhibited naphthene	1	2	Nonemulsifying
Detergent paraffin	2	1	Emulsifiable
Compounded naphthene	3	3	Emulsifiable
Straight paraffin	4	5	Nonemulsifying
Straight naphthene	5	4	Nonemulsifying

TABLE IV.—CONDITION OF AIR PASSING THROUGH 100-LB. SINGLE-STAGE COMPRESSOR.

	Gage Pressure, psi.	Temperature, deg. Fahr.	Relative Humidity, per cent
Atmosphere	0	65	100
Beginning of compression	0	75	74
15-lb. compressor	15	172	12
End of compression	100	485	>1
After-cooler at 138 F.	100	138	100
Leaving after-cooler	100	80	100+
End of transmission pipe	97	65	100+
Tool exhaust	0	35	43

since the rust particles may reach the rubbing surfaces of either the compressor or the pneumatically operated machines. It will be noted from Table III that the five oils were subjected to the ASTM Rusting Test, and the Humidity Cabinet Test and their rust protection qualities compared. It was found that the rust and oxidation inhibited oil and the detergent oil offer the best protection. It can be concluded, therefore, that if good water separation is desired, as is the usual case, the inhibited oil would be preferred. If, on the other hand, water is actually condensing on the cylinder walls, then an emulsifiable lubricant is needed and either the detergent or the compounded oil should be used.

To determine where condensation occurs in a compressed air system, the relative humidity has been calculated at various points. From Table IV, it will be noted that even though air having a relative humidity of 100 per cent is admitted at the air intake of the compressor, the only place that the air becomes saturated in the entire compressed air system is in the after-cooler and in the distribution lines. Thus, an emulsifiable oil is seldom needed in compressor operation, except where: (1) the compressor cylinder jacket cooling water is considerably below atmospheric temperature, or (2) inter-cooling is insufficient and supersaturated air reaches the higher stage cylinders.

The biggest problem met in compressor lubrication is the operator, who, on observing wear, increases the amount of oil fed to the compressor which results in excessive carbonization at the discharge valves. Wear in a compressor is usually due to contamination of the air and seldom to insufficient lubrication. Therefore, an excess of oil should seldom be fed to the compressor even as a temporary expedient.

However, even in the best regulated compressors, carbon may deposit on discharge valves. Therefore, conditions under which this carbon forms deserve consideration. Table V shows the temperatures at the discharge valve at various pressures, and it will be noted that the temperature may vary from 200 F. to 500 F. At the discharge valves the lubricant therefore lies on a flat, often horizontal surface exposed to high temperatures for a considerable length of time. This results in the formation of carbon, the amount and nature of which depends on the type of oil, the compression temperature, and the design of the valve.

TABLE V.—AIR COMPRESSOR DISCHARGE TEMPERATURE.

Compression Gage Pressure, psi.	Approximate Compression Temperature, deg. Fahr.	
	Single-Stage	Two-Stage
50	350	210
100	500	250
200	...	310
300	...	350

In order to select a laboratory test which would correlate with the tendency of the different oils to form carbon on discharge valves, the oils were listed as in Table VI, based on their service performance. It will be noted that neither the oxidation resistance nor the carbon residue tests evaluated the oils in order of service rating. Consequently, it was necessary to devise a special test in which the oil was exposed on a flat plate in a thin film for 24 hr. at various temperatures and the residue determined. It will be noted that this test, as would be expected, checked very well with service experience. It also will be noted that the carbon-forming tendency also varied with the rate of evaporation—the oils which evaporate quickly leave the least carbon.

It will also be noted, as would be expected, that the flash point correlated with the rate of evaporation and the carbon formation. This is of interest in connection with air receiver fires, and on checking several authorities it was found there was general agreement that to prevent such occurrences, an oil having the least tendency to form carbon should be used, and that flash point should not be given consideration since it is a well-established fact that flash point has no relation to autogenous ignition temperature. Incidentally, the ASTM autogenous ignition temperature of the five oils was in each case close to 700 F. Table VII gives the thin film residue test on two of the oils from which it will be noted that, regardless of temperature, the naphthene oil leaves the least residue. Of interest is the fact that at the lower temperatures the deposit was wet and soft and at the higher temperatures dry and hard.

TABLE VI.—CARBON FORMATION INDICATORS.

	Thin Film Residue, per cent at 350 F.	Evaporation, oz. per sq. ft. per hr. at 350 F.	Flash Point, deg. Fahr., ASTM D 92	Carbon Residue, per cent, ASTM D 189	Oxidation Resistance Rating
Inhibited naphthene	5	0.026	385	0.02	1
Straight naphthene	9	0.031	380	0.01	4
Compounded naphthene	10	0.031	395	0.03	5
Detergent paraffin	16	0.010	435	0.37	2
Straight paraffin	22	0.006	440	0.01	3

TABLE VII.—THIN FILM RESIDUE TEST, TYPICAL RESULTS.

Temperature, deg. Fahr.	Thin Film Residue, per cent	
	Straight Naphthene Oil	Straight Paraffin Oil
250	14	37
350	9	22
450	6	13

TABLE VIII.—LOW-TEMPERATURE CHARACTERISTICS.

Oils	Temperature for 30,000 Saybolt Universal sec., deg. Fahr. Viscosity	Viscosity Index, ASTM D 567	Pour Point, deg. Fahr., ASTM D 97
Inhibited naphthene	+10	36	−20
Straight naphthene	+10	36	−20
Compounded naphthene	+ 7	46	−20
Detergent paraffin	+ 4	90	− 5
Straight paraffin	+ 0	100	− 5

The low-temperature characteristics are of importance, for example, in portable air compressors and refrigeration machines. In the latter, the pour point which determines the temperature at which wax may form is an important consideration. In portable air compres-

sors, the temperature at which the oil reaches a certain viscosity, such as 30,000 Saybolt Universal sec., is the major consideration, and it will be noted from Table VIII that the oils with the higher viscosity index have the lower satisfactory starting temperature.

Putting the above information to practical use, let us first consider the conventional single or two-stage air compressor. Under normal operating conditions, any good grade power plant or general industrial oil will satisfactorily lubricate the air compressor. Under special conditions, some of which will be enumerated, the lubricant must be more carefully selected.

Should carbon deposits form on the discharge valve, then either a naphthenic or a detergent oil should be selected. Normally, the naphthenic oils are superior; however, there are designs where the detergent oils have proved most satisfactory. Apparently, the rate of flow of the oil across the discharge valve is the determining factor. If the oil lies stagnant, a straight naphthenic oil is likely to be best. If the oil flows across the valve surface, then the detergent action of the heavy duty oils can be used to advantage. If rust protection is needed, then the rust and oxidation inhibited oils should be used. If condensation of water on the cylinder walls is causing wear, then either the detergent or the compounded oil is preferred. In the rare case where scuffing occurs, the high film strength of the detergent oils can be used to advantage. Where low temperatures are encountered, the higher viscosity index paraffin oils should be selected. If oil-free air is needed as in the case of food processing or diving operations, then a straight mineral nonvolatile paraffin-base oil of fairly high viscosity is needed.

For high-pressure air compressors heavier oils are usually recommended, not only because of the increased compression pressure but often because of the necessity of keeping the stuffing box well sealed. Since the heavier naphthenic oils are rather difficult to manage at atmospheric temperatures, where heavy oils are required, paraffin-base lubricants are generally used. Such oils are also preferred because of their greater resistance to oxidation, which is more prone to occur in high-pressure machines where there is a higher concentration of oxygen. Should valve deposits occur, however, the naphthenic oils should be used. In this connection, as indicated in Table IX, it is interesting to note the extent that viscosity increases under pressure.

Where gases other than air are compressed, straight mineral oils should normally be used, at least with such gases as carbon dioxide, nitrous-oxide, hydrogen, freon, and ammonia. Straight mineral oils are also used with hydrogen sulfide and sulfur dioxide. However, where such gases containing sulfur are used, extreme care must be taken to keep the oil dry and avoid entrance of water into the system. Compressors handling oxygen and chlorine should be built so that no lubrication is required.

TABLE IX.—EFFECT OF PRESSURE ON VISCOSITY OF A TYPICAL HEAVY COMPRESSOR OIL.[a]

Gage Pressure, psi.	Saybolt Universal Viscosity at 210 F., sec. (Calculated)
0	100
5 000	170
10 000	240
15 000	310

[a] Based on Table 3 of "Viscosity of Lubricants Under High Pressure," by Hersey and Hopkins, *Mechanical Engineering*, December, 1945, p. 822.

Where petroleum gases are compressed, there are several factors that must be taken into consideration, such as the absorption of gas by the lubricant. Therefore, normally when compressing petroleum gases the oil viscosity should be about one grade heavier than when compressing air. If the gas contains liquid petroleum, such as entrained gasoline, compounded oils are often used to resist the washing effect. Where unstable refinery gases are compressed, the detergent oils have been found most effective in preventing gum and lacquer deposits. Where petroleum gases are compressed to high pressures, steam cylinder oils are recommended.

Air compressors are used in connection with diesel engine applications. For the starting air compressor previous comments apply. For the injection air compressor, which is usually an integral part of air injection diesel engines, compounded oils are often used. Here the problem is the prolongation of the life of the intercooler made of copper tubes through which the air passes at high velocity. Rapid erosion of these tubes occurs due to the combination of the high velocity and any foreign particles in the air stream. Compounded oils seem to resist this erosion, while the detergent oils, on the other hand, have a scoring effect and tend to shorten the life of the inter-cooler tubes.

The third application of air compressors in diesel engine operation is in the superchargers or the scavenger blowers which furnish air directly to the engine. These blowers operate at high speed and require a light oil for bearing lubrication. Often the same oil used in the diesel engine is applied to the supercharger or blower bearings. However, in most cases, a lighter oil fed from an independent lubrication system is preferred.

Compressors are, of course, the most essential element in refrigeration systems. With rare exceptions, the naphthenic oils having low pour points and good water separating characteristics are offered.

Rotary positive displacement compressors, such as the vane type, require heavier oils to seal the rubbing surfaces and prevent wear. The hot plate effect is absent in these machines, and consequently, paraffin base oils, often containing rust and oxidation inhibitors, are recommended.

For centrifugal blowers, the only lubricant required is for the bearings which are usually grease lubricated. Only highest quality antifriction bearing lubricants are recommended, as this has proved to be rather severe service.

The bearings are the principal elements requiring lubrication on the axial flow compressor, and a light viscosity rust and oxidation inhibited oil is preferred.

A vacuum pump is essentially a compressor operating at an intake pressure below atmospheric and a discharge pressure near atmospheric. The paraffin base oils are generally recommended for vacuum pumps for, being least volatile, their consumption will be lowest. There is also an absence of any heat condition which would require the naphthenic type oils. For high-vacuum pumps, the oil should be most carefully selected, a narrow cut paraffin stock being required. In many applications a considerable amount of water enters at the vacuum pump intake and at the same time the amount of oil leaving the vacuum pump at the discharge valve is considerable. This mixture of oil and water is usually removed from the air by a separator which is an integral part of the vacuum pump. From this separator, the water is drained off and the oil is returned to the compressor lubrication system. It is, therefore, highly important that the oil have good water-separating characteristics. Where the vacuum pump is handling air or other gases containing foreign matter, as in the case in pigment industries, detergent oils have proved satisfactory in preventing deposit formation.

Considerable care should be used in selecting a lubricant for a compressor. However, the problems involved are well recognized and their solutions well known. If the lubrication recommendations of a qualified lubrication engineer are followed, satisfactory performance will be assured.

Colorimetry—A Panel Discussion

THE FOLLOWING is a panel discussion on Colorimetry which transpired at a technical session of Committee D-1 on Paint, Varnish, Lacquer, and Related Products of the American Society for Testing Materials. It was held on Wednesday afternoon, March 1, 1950, during the Spring Meeting of the Society at the William Penn Hotel, Pittsburgh, Pa.

A panel discussion on paint testing held in Chicago the previous year (see ASTM BULLETIN, October, 1949, p. 39) has been so well received that the Papers Subcommittee felt a Panel Discussion on Colorimetry this year might be in order.

Moderator for the Colorimetry panel was Walter C. Granville, Container Corporation of America. Members of the panel were Francis Scofield, National Paint, Varnish, and Lacquer Assn., Inc.; Richard S. Hunter, Henry A. Gardner Laboratory; M. P. Morse, E. I. du Pont de Nemours and Co.; and E. J. Dunn, Jr., and A. E. Jacobsen, National Lead Co.

C. C. Hipkins, Bell Telephone Laboratories, as Chairman of the Subcommittee on Papers for Committee D-1, introduced Mr. Granville as moderator. The rest of the panel members, in turn, were introduced then to the audience by Mr. Granville. Participants in the discussion, from the audience, were M. R. Euverard, Interchemical Corp.; B. A. Silard, Photovolt Corp.; L. A. Melsheimer, Calco Chemical Div., American Cyanamid Co.; G. G. Sward, Scientific Section, National Paint, Varnish, and Lacquer Assn.; and G. L. Erikson, Braden-Sutphin Ink Co.

MR. GRANVILLE.—The purpose of this panel discussion is to bring to the attention of the members of Committee D-1 a discussion of some of the most recent techniques and thinking regarding color measurement and specifications and control, as it applies to the general interests of this group.

First, why is color standardization a problem? To me it seems that the main reason is the eye can see so many different colors, or the eye can distinguish between surfaces that differ very little in color. Estimates have been made that the number of different colors which can be distinguished by the eye are of the order of five million. I put on the blackboard the figure one million, as a conservative estimate of the number of colors which the eye can distinguish; possibly we may modify that figure as we go along in the discussion.

In this group, color is measured and specified in several principal ways. It is specified in terms of a retained sample of a product, a paint, or a varnish; it is specified in terms of fundamental physical measurements on the particular article, such as spectrophotometric curves; or it is specified in terms of some intermediate primary standard, the measurement describing the relationship between the color in question and the standard. There seems to be no one set of color terms that is suitable for all uses in our own particular field. Thus there are certain terms which while familiar to this group are quite unfamiliar to other groups, so you will have to bear with the members of the panel when they use perhaps similar terms for different things. They may use the word *color* to mean *paint;* they may use it to mean visual appearance; or they may use it to mean an energy distribution—a certain type of light. In other words, you have psychological, psychophysical, and physical meanings.

To help you understand further some of the panel members' comments, you might think of the problem of color measurement as relating to a light source, a surface (a light modifier), and the eye which is the receptor of the light reflected from the light modifier which could be a paint or varnish. A photocell, of course, can be substituted for the eye. Also relating to the problem is a fourth part, in back of the eye—the brain. I think that can be considered almost as a separate entity. So you have four separate factors in this problem of color measurement, the light source, the modifier, the receptor, and the interpreter—the brain.

First in this relationship between colorimetry and paint we might discuss the control of working standards for visual comparison and ask members of the panel for comment. Perhaps Mr. Scofield would have some comments on control of working standards.

Control of Working Standards for Visual Comparison

MR. SCOFIELD.—In light of what Mr. Granville said a little earlier, the eye can see differences at least as accurately as we can measure them. Also the eye is an extremely convenient instrument, being usually readily available and only rarely getting out of adjustment. Therefore, for the routine matching of color the visual comparison with a standard is by far the simplest, and under proper conditions the most accurate method we have.

However, we have the problem of being sure that the standard with which we make the comparison does not change. There are several ways of solving it. The fact that there are so many ways is testimony to the effect that none of them is completely satisfactory.

We can retain a wet sample of the material, and when that is almost exhausted we can make up a new one to match it. But I think many of you are familiar with the misadventures you get into in a few years using that procedure.

You can retain dried chips, putting them away in a drawer with the hope that they won't get lost or dirty. Also you trust that they won't get yellow in the drawer as they sometimes do.

The most satisfactory method probably is the measurement on some instrument, spectrophotometer or colorimeter, which, though it doesn't have quite the accuracy of the trained eye, has a memory and can "remember" the color of a year ago as compared with the color now. Therefore, a new working standard can be made up to match the original. For some reason or other this is done only in a limited number of cases. Maybe people don't trust the instrument too well.

MR. HUNTER.—There are a lot of problems in getting satisfactory color control with an instrument. A little dust may get on the lenses, or the optical adjustment of the beams may change enough to change the geometry of illumination; as a consequence, the result that the instrument gives one year may differ slightly from that given the year before.

The situation is much improved if you can use at all times reasonably permanent color standards, such as panels of porcelain enamel, or opaque glass. You then measure each of your paint colors relative to the permanent panel closest to it in color. I know of some companies which are doing this at the present time and I believe they are having success.

The fact that instruments are, as you have said, not so accurate as the human eye causes the paint manufacturer to hesitate. He doesn't completely trust them.

MR. DUNN.—I might cite an experience of ours. I am perhaps a little more optimistic than these other two gentlemen who have spoken just now about maintaining standards. We were confronted with the same problem

and resorted to the General Electric recording spectrophotometer, because it seemed to be the accepted instrument. We obtained the fundamental data on a series of paints, kept the paints for approximately a year, and remeasured them. Finally we made up new paints and determined the fundamental data. We have been led to believe that we should not expect any correlation among such a series of samples. However we found surprisingly small differences. The differences found were primarily what you would call lightness differences. If there is a color difference you immediately want to know what kind. Is it a difference in going from the white end of the scale to the black; is it in going to greater depth of color; or is it a change of wave length or hue around the color solid? With our colors the main difference was primarily a change in lightness, or a change in the general reflection. The two curves we obtained for the original, and after a year of aging of the sealed can of paint, were almost duplicates. The total curve may shift as much as one per cent, and that is enough for the eye to see readily; but from the point of view of practical considerations—from a production organization—it is a reasonable match. It is not a close match by many color difference measurements and by equations used to express color differences, but it is an accepted match.

So I inject just a little note of optimism here. I don't think the problem of maintaining color standards is quite as bad as the color experts put it.

MR. SCOFIELD.—One point has been overlooked—unfortunately the process is cumulative. In other words, the standard has darkened, you make up a new one to match the standard, the next year the standard has darkened some more.

One paint manufacturer told me that he was making a blue for many years with ultramarine shaded with lampblack. When he restudied the original formula, he found it had started as pure ultramarine and through the years increasing amounts of lampblack were added in order to match the so-called standard.

MR. DUNN.—Of course if you use this year's paint a year hence as your color standard that may be true. But if you use chromaticity coordinates, excitation purity, dominant wave length, lightness factor, and similar functions, *anytime* you make a paint to match the data you are not shifting your color standard. You don't require the can of paint as standard. You do require the fundamental data and you can always maintain a color if you make your paint to match the original fundamental data.

MR. GRANVILLE.—Of course these differences Mr. Dunn's talking about are considerably larger than the smallest difference that a shader usually can detect.

I recall some work done by the New York Paint Production Club fourteen years ago, when a few selected pigments were ground in six different vehicles, canned, and then measured on the General Electric spectrophotometer immediately and also after a period of about 18 months. The curves for the after- and before-aging period were in most cases about the same but they were separated by ½ to 1 per cent. At that time—fourteen years ago—we were not sure whether the photometric scale, some detail of measurement, or the paint itself had changed.

These instrument techniques are developing greater reliability and I think it is encouraging to hear Mr. Dunn say that he can now interpret as significant a one per cent difference.

But I am just a little suspicious, because that change in level of the curve can be due to a change in the distribution of the vehicle throughout the paint. If the pigment tends to settle out and isn't dispersed to the same extent that it was originally, you will get a higher reading. I think in 1918 Merwin found that by taking a paint and just adding more vehicle to it the reflectance curve was raised two or three per cent.

So when you get these differences you begin to wonder. Is it due to a color change—or what kind of a change is it? Wouldn't you say there is still some problem?

MR. DUNN.—I think that is very true. In a laboratory where you are responsible for trying to hold a color, you could do it by this procedure. But if you were considering visual comparisons of paint out in the factory and didn't add the same quantities of vehicle you may get what appear to be lighter and lighter colors to the eye. Photometrically these may give you the same color analysis. In other words, there are such characteristics as gloss and texture which affect the appearance of colors to the eye and you must take these characteristics into consideration also.

MR. MORSE.—Our experience is apparently similar to Mr. Dunn's in that connection. We are using the Beckman spectrophotometer to control our white dry-plate standards. We measure the standard of a particular product on the spectrophotometer and calculate values which, it appears to us, determine the color of this material. Since a large batch of these standards is made at one time, once a month one panel from the batch is checked on the spectrophotometer and these values calculated again and compared with the original values.

If we find after several months that the values have drifted gradually in a particular direction, it is time to renew the color of the standard. The dry-plate standards are remade to correspond to the original values established for the product. We have been quite surprised to find that some of our whites which we thought were permanent were proved to be not permanent and in need of replacement rather frequently.

MR. JACOBSEN.—What do you consider as your primary standard for the spectrophotometer?

MR. MORSE.—We consider magnesium oxide to be the primary standard but since we find magnesium oxide difficult to prepare, we use a piece of white vitrolite glass which has been very carefully standardized by the National Bureau of Standards. We refer all of our reflectance values to this piece of vitrolite. We do not convert values to a magnesium oxide basis, but keep them all on this vitrolite basis.

However, multiplying the sample reflectance values by the vitrolite values converts to a magnesium oxide basis.

MR. JACOBSEN.—Our experience over the years has shown that the National Bureau of Standards has been doing a better job in evaluating standards than was possible say ten years ago. I think we are now able to obtain reasonably reliable and reproducible standards if there's need for replacements. In other words, if your standard is scratched or destroyed, you can obtain a replacement standard which will give values corresponding to the original.

I think this is a great help. We are now better equipped for making small color difference measurements. Without suitable standards (regardless of the accuracy of the instruments which were thus available) it was impossible for us to obtain any real correlation between laboratories or even to study samples of paint or pigment and know that the values were reproducible from year to year.

MR. HUNTER.—This is an important point. Every instrument used for color measurement anywhere is merely a comparer of unknowns and standards.

MR. GRANVILLE.—To summarize the matter of control of working standards for visual comparison, our instrument techniques are improving and we are able to make more accurate measurements. However, the eye can still see smaller differences than can be measured with surety. The principal problem then, in use of working standards for visual comparison, is to control the standard by which the comparison is made. Do you gentlemen agree for the most part with that?

Accuracy of Color Measurements

This leads us to the accuracy with which one can make these color measurements. There are several different methods, in general, that might be used. You can use spectrophotometers or you can use working color standards and make the comparison with the sample either visually or with a colorimeter.

Mr. Hunter, what is your feeling about the accuracy of present-day colorimeters for color measurement?

MR. HUNTER.—I judge you mean the tristimulus photoelectric type of colorimeter with filters designed to make them respond to different wave lengths in nearly the same manner as the normal human eye.

In general, the colorimeters can be made accurate instruments for the measurement of color differences. That is, you can duplicate the results today that you obtained yesterday. But they are not accurate in the sense that they will give the exact color specifications for any material on our so-called I.C.I. basis. This is because our filter and photocell combinations are not exact duplicates of the spectral response functions of the human eye.

Of course, as a result of Jacobsen's now famous work, we have called the I.C.I. standard observer into question. Jacobsen, you will remember, discovered about two years ago that his color matchers at Sayreville were not obtaining the same yellowness comparisons of rutile and anatase titanium pigments as he obtained from spectrophotometry and computation with the I.C.I. observer. When he asked Dr. Judd at the Bureau of Standards about this, he was told, "It is fairly apparent that your raters have a greater response to the shorter wave lengths of blue light than the standard observer." So even our standard observer is in question.

I say this to emphasize that to obtain what we might call absolute accuracy in color measurement is very difficult. By absolute accuracy I mean numbers exactly representing a color as an absolute average observer would see it.

On the other hand, difference measurements can be made with high precision when we are comparing one sample with another one very much like it. In the color-difference meter I think we can detect any color difference that a trained observer can see. I don't believe we can do better, but I do believe we can do practically as well.

MR. GRANVILLE.—You mean, if given a permanent standard and then a batch supposedly near in color to it, you can make a very precise determination of the color difference between the standard and the batch by means of a colorimeter and get useful information?

MR. HUNTER.—That is right.

MR. SCOFIELD.—Mr. Hunter brings out one point that needs emphasis. It is almost without meaning to say that an instrument is more precise than the human eye, because we have no way of knowing whether there is a real color difference unless we can see it.

I think there is one other point, in that connection. It has been my experience that color measurements made on a colorimeter, a single instrument, particularly by a single trained operator, can have extremely high precision (reproducibility) all of the evidence I have is that in many cases they agree pretty well with the visual judgments—but we have little or no information as to how the reproducibility or agreement between two different presumably identical machines would be. Of course, the accuracy is limited by the accuracy of the particular standard used. If it is a difference you are measuring, that is something else, but for absolute values on any colorimeter your accuracy is limited by the accuracy of the standard you use.

MR. MORSE.—A few minutes ago I said we were using spectrophotometers in our work. The reason for that is that we have yet to find a colorimeter that we consider entirely satisfactory for the measurement of small color differences, particularly, small differences in whites. I think Mr. Hunter and Mr. Scofield are right in that the precision of colorimeters is high, if they speak about colors which are not neutral, such as whites. But in the case of whites we have found that the present colorimeters are not precise enough to detect the small differences. Therefore we use the spectrophotometer which scarcely gives the precision necessary.

Although the question was about accuracy, all this talk has been on precision.

MR. HUNTER.—We admitted that the accuracy wasn't satisfactory.

I will admit further that the smallest difference in color ever shown me was that between two white refrigerator enamels furnished by Mr. Morse.

MR. GRANVILLE.—Well, accuracy seems to be a problem even with the spectrophotometer. You say, Mr. Morse, that the instrument is scarcely able to measure these small differences.

MR. MORSE.—That is right. Furthermore, it is not enough to just get a measurement with an instrument. The question is how to translate reflectance values into color differences that an observer would see. You must have a system which will agree quite well with what an observer would see. So it seems to me the test of the accuracy of an instrument is whether the results, after you interpret them agree with what you see visually.

MR. GRANVILLE.—We always seem to revert to the eye as the criterion of minimum perceptibility.

How about colors other than whites, Mr. Morse? I heard you make the statement that you didn't like to be limited to matching the same spectrophotometric curve and duplicating it, since there was even some indication of variation. Would you discuss, for a moment, the difference between batches?

MR. MORSE.—It is our experience that the small differences we look for in whites are small differences indeed, in spectrophotometric curves. If you had a white sample that appeared slightly yellow to the eye with respect to the standard and both were of approximately the same composition, the spectrophotometric curves would be extremely similar.

MR. GRANVILLE.—Would they be parallel?

MR. MORSE.—No, they would not be parallel. The reason is that yellow or blueness in a white produces a curve that is slightly dipped, that is, the slope is slightly different from that of the standard. For instance, if you subtracted the average reflectance in the blue region from the average reflectance in the yellow—red regions for both sample and standard and found a difference as much as 0.15 per cent between the values for standard and sample, a visual difference would be present. So you can see that your chances of detecting small color differences by comparing spectrophotometric curves are slight. In my opinion you would have to actually work with the reflectance values rather than the curves.

MR. GRANVILLE.—I see. Would this be a fair statement? Suppose you have a series of batches of white. They can be represented by a family of curves differing from each other by very small amounts, but none of the curves are parallel to one another. Though you may be looking for differences in one region, the variations in that region may be different for each batch. In other words, five batches which you consider visually to be the same color may differ from one another by small counteracting amounts (plus in one region is counteracted by minus in another). Is that correct?

MR. MORSE.—Yes, that is correct, because color matches in the paint industry are made customarily under one type of illumination, which is usually considered as north daylight or its equivalent. So, considered just on that one basis, it is possible to have perfect visual matches and yet have different spectrophotometric curves.

MR. GRANVILLE.—They may be slightly different or may be greatly different?

MR. MORSE.—That is right.

MR. GRANVILLE.—You mean then that you can have a whole series of panels which look the same to the eye and yet have different spectrophotometric curves?

MR. MORSE.—That is right.

MR. GRANVILLE.—It could be inferred then that if you had a panel for every color the eye can distinguish, that is, a panel for every one of these one million colors, you could, for any one color, develop a series of panels which would appear the same but might actually differ if you changed the illumination. Or in other words, if you wanted to make a panel for every color, so to speak, one million is just the lower limit. How many different curves would be possible for each color? Could you get ten, or fifty, or a hundred? Would you be willing to make a rough guess as to the order of the number possible?

MR. MORSE.—I could probably; but—

MR. GRANVILLE (interrupting).—Just for the sake of argument let's say that this means the figure of one million has to be increased 100 times (we have to add two zeros for the number of different colors with which we are working in practice). This number that the eye can distinguish seems to become larger and larger, provided the eye is given the opportunity to do it.

MR. DUNN.—I'm a little more optimistic than some of the other discussers. Many years ago our group examined about 15 different colors on the Beckman spectrophotometer, the General Electric spectrophotometer, and the Hunter multi-purpose reflectometer; the color difference meter was not available at that time. After we calculated the fundamental data, we gave the data to a statistician and asked him to tell us which set of data best represented each color. We never received a satisfactory answer from that statistician as to which were the best data to use. The thing that amazed us was that the differences among all the data were small. Now these are quite different instruments. The light for the General Electric enters an integrating sphere; in the Beckman the light is reflected from the surface to an angular ring which accommodates a cone of light of 35 to 55 deg. With the color-difference meter I believe the light enters at a 45-deg. angle and is viewed normal to the surface. Thus, there were wide differences in design of measuring instruments but the results were so similar it was difficult to decide which colorimetric data to use for these colors.

MR. GRANVILLE.—In other words, for certain types of samples, the instrument you use and the technique of viewing and illuminating are of lesser importance?

MR. DUNN.—The greater difference seems to come in the deeper colors.

MR. JACOBSEN.—I feel we are doubting results which have been accomplished over the years by the technicians and the instrument makers for improvement in determining color or small color differences. There seems to be an increase in the reproducibility and agreement between instruments just as there have been improvements in standards. The older instruments were not able to satisfy today's demand for a high degree of precision. But with the advancement in knowledge of the spectrophotometric data and with newer modifications of spectrophotometers, it is now possible to read smaller differences. In our own spectrophotometer, its present range, at the blue end, begins at 390 instead of 400 mμ and if we consider 10-mμ increments, the over-all spectrophotometric curve enables us to show differences which, as Mr. Hunter has said, were not shown before because of failure to recognize the importance of the lower blue wave-length range. As alternates to the spectrophotometer, the newer colorimeters have a blue filter which accommodates more closely the response to the eye. In the older colorimeters, the blue filters, did not accommodate the eye response so closely.

I want to caution those who are engaged in any cooperative work that there are differences in the blue filters, and in the event that correlation is not obtained perhaps it would be well to determine and evaluate the spectral distribution or transmission distribution of these filters.

MR. HUNTER.—Mr. Jacobsen has made a good point. In our company we have been putting what we call "Jacobsen-blue" filters in all of our instruments for about two years. So these blue filters, less than two years old, will be slightly different from those more than two years old.

MR. GRANVILLE.—I don't want to give the impression that advancements haven't been made in measurement techniques; actually, they are being made frequently, enabling measurements of greater accuracy and precision. However, this ability to measure more accurately is showing things we didn't know too much about before—small color differences which are becoming important—differences we didn't know of before because the accuracy of our measurements was not such as to disclose them. One of the principal problems we seem to have now is that of viewing and illuminating geometry. Do these instruments view the panel or, if it is by transmission, do they view the varnish sample or oil in the same way that an observer does when he holds it up and views it? Is the sample illuminated by the instrument as it is in human-observer practice? The newer advancements in instruments are such that these variations in manner-of-viewing and method-of-illuminating are becoming important. We are working with smaller differences disclosed by improved instruments.

As Mr. Jacobsen has mentioned, the problem of whites was critical until he found out how to get agreement among observers.

I believe the audience would like to hear a discussion on how instruments view and illuminate samples? How is that important in our work?

MR. HUNTER.—I was thinking, as you were writing on the blackboard the number representing colors the eye can distinguish, that if you wanted to consider the gloss variable as part of the color variable, you could add three or four more zeros to the number.

MR. GRANVILLE.—In other words, would you say that you could have one color and maybe a hundred or a thousand variations within that color due to the texture and gloss of the panel?

MR. HUNTER.—That is right.

MR. GRANVILLE.—So we could add three zeros to be conservative. This number is 100 billion now. I think we have gone far enough.

A MEMBER.—Do you mean that many different standard panels could be required now?

MR. GRANVILLE.—It is possible. The eye could distinguish between that many different panels. So you see it is really remarkable that instruments enable us to get intelligence with respect to color and gloss to the extent that we can get it, when there are so many possible variables. These variables are not just theoretical. Given enough time you could make that many panels.

MR. HUNTER.—Of course the simplest basis for discussion of illumination geometry is on the division of light reflected by a specimen into two components, one reflected by the surface in the direction of the mirror reflection, and responsible for the gloss that the panel appears to have. This beam is in general colorless, although in the case of bronzy printing inks and paints, it may have distinct chromatic appearance.

The other component of light reflected by the surface is said to be diffusely reflected. Traditionally it is said to be reflected uniformly in all directions. It consists of light reflected by the pigment body of the material, and therefore it carries the color of the pigment. The simplest treatment of this problem of illuminating and viewing geometry is to say that we want to use some

arrangement that does not include the specular beam, since this beam is always excluded by the color matcher. He always holds the panel so that he doesn't see a high light when he is making a color comparison.

The true picture isn't quite as simple as this. Except for high-gloss enamels that reflect distinct mirror images, there is no exact or absolute way of separating specular and diffuse reflectance. Nevertheless, I think for practicable purposes, the majority of samples may be accurately compared for color with 45-deg. illumination and normal viewing or *vice versa*. There is some evidence that 50-deg. would be better than 45-deg. illumination, but this improvement is not enough to make any significant difference.

We have a new goniophotometer with which we are getting some data on this subject for the first time. We are interested in the fact that even materials which are considered to be uniform in color in all directions, actually change color as angles of illumination and view are changed.

MR. GRANVILLE.—This is the old problem of having two samples that look alike at one angle and different at another. It is this problem of viewing at different angles which we are only now just beginning to make rapid progress in its solution.

MR. HUNTER.—This is most critical to the paint man who is given a flat paint for an interior wall and told to make up a glossy trim color to match it. I am told that the standard procedure for this—and I have no better solution to suggest—is to wet the flat paint with sputum and rub the wet spot with the finger until it acquires a glossy appearance. This wetted flat-paint spot is then matched with the glossy paint.

MR. SILARD.—I wish to take exception to a remark by Mr. Scofield that there is no easy way of determining the accuracy of an instrument that will measure "better than the eye." Suppose we construct an instrument scale (drawing on blackboard). I am marking points zero and 1 on the scale, for two samples that Mr. Scofield has designated as so close together that the matcher cannot make out any smaller difference.

If this instrument gives reproducible results, it will always show zero for one sample and always show 1 for the other sample; then, introducing a third sample, which let us assume would appear on the scale, one tenth of the distance between the other two sample values. I would say that I could rely upon the instrument to show roughly one tenth of the smallest visually determined color difference.

If this is not quite clear, I can show you a second method. Let's assume that the first "zero" sample almost matches the second "one" sample and that you cannot see any smaller difference. Put these two panels on a disk; half a disk is for zero and the other half is for one; let the disk rotate. Thereby you mix the two limits of matching and get an intermediate color that the visual matcher cannot distinguish from zero or one. But if an instrument discriminates properly from these, I would say this instrument is twice as sensitive as the eye.

The Photovolt instrument, which is not new, is probably not as sensitive as the Hunter colorimeter. It will be somewhere between the Hunter color-difference meter and the older Hunter instruments.

MR. MORSE.—On this question of differences in illumination and viewing, while investigating instruments for measurement we examined the General Electric and Beckman spectrophotometers, which are quite different in their provisions for viewing, the G.E. instrument viewing at all angles to the surface whereas the Beckman views the sample at a 45-deg. angle. We found that either instrument will measure color differences and by proper interpretation of the results each will agree with what you see with the eye. But the absolute values are not the same. So if you use the General Electric instrument for tristimulus values and determine these later with the Beckman instrument, it is likely that they would not agree.

MR. GRANVILLE.—These comparisons are valid when the gloss of the two samples is identical. If, among the conditions of Mr. Silard's illustration, there is a slight difference in gloss, the instrument may or may not interpret it as a color difference.

MR. MORSE.—I have something to say on this too. When using the Beckman spectrophotometer which views at 45 deg. from normal, we find that we get the same reflectance, relative to vitrolite, for samples of the same color regardless of the gloss of those samples.

MR. GRANVILLE.—This occurs when you use a diffuse technique?

MR. MORSE.—Yes. This is true when using the Beckman but not when using the General Electric instrument.

MR. SCOFIELD.—I should like to describe an even more spectacular case of differences because of change in viewing angle. I had occasion to examine the color of some wood panels with a clear finish on them. I was using an instrument that illuminated at 45 deg. and viewed normal to the surface. If the direction of viewing was parallel to the grain of the wood, fairly reproducible results that correlated with visual judgment were obtained. But if the direction of illumination was normal to the grain, much higher and totally meaningless results were obtained.

MR. GRANVILLE.—I should like to call on Mr. Erikson.

Fluorescent Pigments

MR. ERIKSON.—A discussion of this kind is very interesting. In the printing-ink field with fluorescent pigments and I was interested in the comments on the white problem. We don't have a difficult problem with whites in the ways that the discussion has outlined. But isn't it possible to have different batches of whites that may carry different amounts of fluorescence in their finished paints, and give radically different results, depending on whether you use a spectrophotometric instrument or color-difference meter, or similar instrument which measures the beam as reflected to the eye rather than breaks up the light beam initially?

What are the relative merits of the spectrophotometer and these colorimeters, in measuring colors, when there is fluorescence?

MR. MORSE.—I would say that neither instrument is adjusted to take care of fluorescence. But cretain adjustments can be made.

MR. HUNTER.—The color-difference meter is best.

MR. DUNN.—But it's possible to cancel out the fluorescence in your reading. You can also obtain a curve of the fluorescence with some spectrophotometers.

MR. SILARD.—I wouldn't agree with what Mr. Morse just said. A colorimeter properly designed will evaluate fluorescence of the paper, or of the paint, as the eye would see it. The method is to position the receptor with respect to the sample so that it will pick up the fluorescence the same way the eye would. That is not possible in a spectrophotometer or anything else where the receptor is far removed from the sample.

MR. GRANVILLE.—I think Mr. Morse was referring to the current model of the General Electric instrument.

MR. SILARD.—Neither the General Electric nor the Beckman instrument will, but Hunter's instrument, so far as I know, will evaluate fluorescence the same as my instrument views it.

MR. GRANVILLE.—Will you agree with that, Mr. Hunter?

MR. HUNTER.—Yes. However we use incandescent light, and I think they rate Solium visually in daylight. Thus we have a difference in illuminant.

MR. SILARD.—That is right.

MR. GRANVILLE.—Does anyone wish to comment on this?

MR. JACOBSEN.—Solium is dependent upon the ultraviolet illumination to give appearance. If the instrument does not subject the sample to any ultraviolet

light you are not going to get any response in the instrument.

MR. ERIKSON.—But daylight contains ultraviolet.

MR. JACOBSEN.—That is the difference. You will not observe it with certain instruments but you will see it in daylight.

MR. GRANVILLE.—You will recall the first model of the Hardy recording spectrophotometer dispersed the light after it was reflected from the sample, and in that way any fluorescence was included in the measurement.

Cost of Color Control Instrumentation

MR. EUVERARD.—I should like to ask Mr. Dunn a question: But first, when you consider instrumentation for color measurement or color control you not only have to consider instrumentation but also trained personnel for its intelligent use. There is probably no single question that has been asked more frequently in the past two years than this one: How much does it cost? My question is: If a medium-sized paint manufacturing company wanted to utilize in its work instrumentation for color control, what would be the minimum amount that should be specified for this instrumentation in the yearly budget and what would be maximum?

MR. DUNN.—Of course, there is no maximum; the firm can spend any amount. These instruments range from $500 apiece to $15,000. It is just a question of how much color control is wanted. But a small laboratory can get the original colorimetric data from a consulting laboratory very reasonably, and then can use good viewing devices for comparison on a reasonable if limited basis. In dollars then, the cost depends on how many colors you are considering and also the scope of the work. A minimum investment probably would be $1000.

MR. SILARD.—What would be your return for $1000?

MR. DUNN.—The data needed from some consulting laboratory, the viewing equipment, the auxiliary equipment and a tristimulus colorimeter. The cost may prove to be a little higher than $1000. It usually runs higher than you anticipate.

MR. GRANVILLE.—Perhaps this is another way to say it. You can calibrate your working standards with a spectrophotometer at some laboratory for a fee, and then make your comparisons visually between the production samples and your calibrated standard sample. Then the cost is much less.

MR. EUVERARD.—My question was based on the assumption that you would buy an instrument, spreading its cost over the years, and also that you would estimate the personnel cost in the organization for the operation of the instrument.

MR. HUNTER.—I was thinking that Mr. Euverard wanted personnel included in that estimate and I think that this personnel cost would be the biggest cost. Wouldn't it, Mr. Dunn?

MR. DUNN.—Yes it would. The cost of the cheapest colorimeter and accessory equipment you could assemble would approach $1000.

MR. MORSE.—I think I can give a partial answer to Mr. Euverard's question.

We looked at this colorimetric work in the light of your question. We first surveyed the field to define suitable instruments. After we selected spectrophotometers we still had a choice of at least two—General Electric and the Beckman instrument. I must say that the cost of the General Electric, as much as anything else, made us decide to buy the Beckman. You can buy the Beckman spectrophotometer with all accessories, including batteries, for $1500, while I believe the General Electric spectrophotometer sells for $9000 or $10,000. Not only the initial cost of the General Electric is much greater, but the cost of maintenance of the General Electric spectrophotometer is quite high since it requires the supervision of a technical man. The Beckman spectrophotometer, so far as we are concerned, requires very little maintenance, and what maintenance is required can be easily carried out by a trained nontechnical person. The General Electric spectrophotometer requires a very large space, while the Beckman requires very little space since it is a bench instrument and the battery can be set behind it. The ordinary control laboratory in a paint factory is small; at least ours is, and doesn't have the space for a General Electric spectrophotometer.

For these reasons, the $1500 instrument has been selected.

However, one disadvantage of the Beckman instrument is that it must be manually operated. The General Electric spectrophotometer is automatically operated.

But as I pointed out before, the advantage of the G.E. instrument—automatic recording—is lost, as far as we are concerned, because we find it necessary to work with reflectance values, not with curves. After you have obtained the General Electric curve you must spend time to convert it to individual reflectance values. Or you must stand by the instrument and stop the counter on the instrument at the particular wave length you want to measure. This takes more time than if you converted the curve to values. So we feel that the need for actual reflectance values makes the total time of operation for the two instruments almost the same. We also find, with the shortcut of calculation we have devised (we do not convert the complete curve on our paint, but only 12 selected wave lengths) using certain simple formulas involving only addition and subtraction, that anyone can easily test a sample and calculate the required color values in 15 min. This permits the measurement of approximately thirty samples in an eight-hour day.

MR. EUVERARD.—Thank you very much, I appreciate this information.

MR. MELSHEIMER.—Would you use the same ordinates, or wave lengths, in all colors, or do you vary these with the paint tested?

MR. MORSE.—So far, we are using our method only on whites. We have established a method on reds which is, I think, the same except that two wavelength selections have been changed. It appears that other colors are going to work satisfactorily with our method, but I think in each case we are going to have to select a few different wave lengths.

MR. MELSHEIMER.—I see. Thank you.

Each Color, a Different Problem

MR. GEORGE SWARD.—You talked considerably on the different appearances that a single sample can give under different viewing conditions.

So, a family of curves for each sample is accumulated.

But can't the process be reversed? Can't one curve represent different samples under different viewing conditions and thus reduce the apparent number of different colors?

MR. GRANVILLE.—Mr. Sward is not asking this entirely in fun and he yearns for a simpler picture as we all do but I don't believe you can work backwards that way.

MR. SWARD.—Yes, you can. Suppose you have a curve like this (drawing on blackboard) under a given condition of viewing, and like this under another condition. But another sample under a third condition might appear like this first curve or the second one. In other words, sample 1, condition 1, gives the same curve as sample 11, condition 11. Therefore, a thousand appearances or even a million may require only a thousand standards.

MR. GRANVILLE.—I was talking about the appearance of a sample and was referring to the many spectral distributions which would be needed to specify an equivalent stimulus for various modes of viewing. I think that each color would present a different problem and believe that your scheme cannot be worked backwards because a

different spectral component will be added to the same geometric component for each color. Thus in terms of your illustration sample 1, condition 1, might produce the same curve as sample 11, condition 348.

MR. ERIKSON.—How many different curves could you draw on a spectrophotometer and distinguish them? I think that is what Mr. Sward has in mind.

MR. GRANVILLE.—It has been said that the largest number known to colorimetry is the number of different spectral distributions that are possible. So, I think, even if the scheme could be worked backwards, it still would not reduce the number of samples or spectral distributions needed.

MR. SWARD.—There is also one more question. Mr. Morse said you couldn't differentiate between the curves; you couldn't identify the results. The curves would differ a little at one end; therefore, you would do better to take your values and change them. But where do you get your values?

MR. MORSE.—You obtain reflectance values directly with the Beckman spectrophotometer, while you can obtain reflectance values from the curve of the General Electric instrument. When you superimpose curves, you can see there is a difference, but you may not be able to tell by looking at the curves whether one is bluer, greener, or yellower then the other. You must convert the difference into numbers.

Summary

MR. GRANVILLE.—I should like to summarize a few of the points we have discussed today.

First, people always will be concerned with small color differences because they can see them.

The use of instruments in color matching and color control has increased greatly in the last decade, and the use, not only of spectrophotometers but of other instruments as discussed here for color control, has developed and I think that activity can be expected to increase.

Nevertheless, some paint companies most vitally interested in color control for paint do not use instruments but rely entirely on retained samples of color and visual comparison.

The principal problem at the present time with regard to measurement by instrument concerns illumination and viewing conditions in colorimetry. That is, measurements now being made are of such accuracy that variations in the surface characteristics of samples interfere with the accurate measurement of small color differences.

A Universal Loading Machine for Engineering Tests on Soils

By B. K. Hough[1]

IN equipping a soils engineering laboratory for general-purpose testing, research, or student instruction, procurement or development of suitable loading machines is a major problem requiring careful consideration of functional requirements and best usage of available space and funds. A limited number of such machines may now be obtained commercially but these are, for the most part, intended for use in only one type of test such as direct shear, triaxial shear, or consolidation testing. Several different machines, each with its own loading and load measuring systems, are often considered necessary under these circumstances. A complete assemblage of such separate units requires several times the floor space which would be occupied by a single, multi-purpose machine and often involves unnecessary duplication of certain loading and weighing components. A single loading machine for all the strength and compressibility tests now conducted for soils engineering purposes would, therefore, be desirable in many installations. A universal or multi-purpose machine of this type has been developed as described herein and has now been tested in actual service for several years. It has not only the advantage of being an individual, compact unit but also affords greater flexibility in load application and measurement than has previously been available in some of the older testing equipment.

The new machine, as depicted in Fig. 1, occupies a floor space of only 24 by 30 in. and has a height of 82 in. It is in part pneumatically operated and requires connection to a source of compressed air. The models constructed to date have been built for connection to a centrally located air compressor but an individual compressor could be installed within each machine, if desired, making the units entirely self-contained except for an electrical connection.

The machine features two separate loading and load-weighing systems, one vertical and one horizontal, so arranged that either one may be operated individually or both together. The simultaneous operation of these systems makes possible the conduct of direct or transverse shear tests of any type in which both normal and tangential load application and measurement are required. The vertical system alone is suitable for compression testing of soils and for applying axial loading in triaxial and unconfined compression tests. For the triaxial tests, a third system is available for applying and maintaining lateral pressures. Each of these systems is described below.

Vertical-load application and measurement are both accomplished by means of the loading head which may be seen more clearly in Fig. 2. The essential feature of this unit is a flexible diaphragm which can be loaded by air pressure on its upper side. The downward force produced in this manner is transmitted to a pressure foot extend-

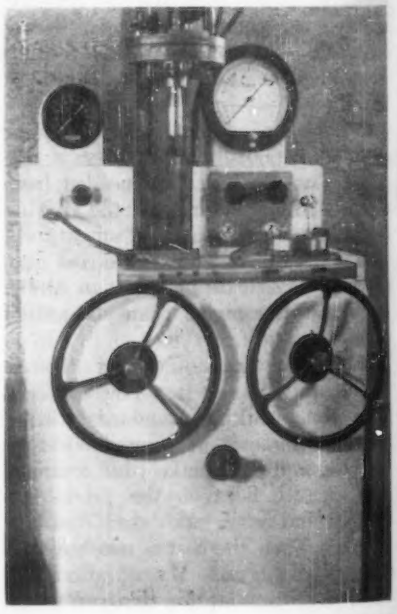

Fig. 1.—Universal Loading Machine for Soils Engineering Tests.

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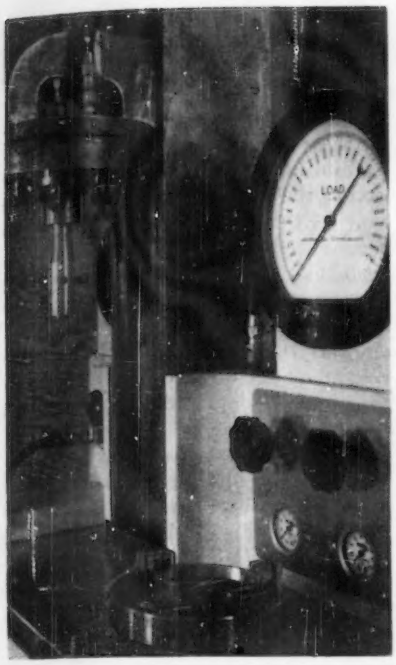


Fig. 2.—Close-Up View Showing Loading Head.

which, in contrast to a conventional yoke arrangement, permits complete access to the specimen on all sides except the rear. The head may be attached in any one of a number of positions and once secured is capable of being moved with the column through a vertical distance of 4 in. Both manual and power drive are provided for the vertical movement which is obtained by operation of a screw jack attached to the column. In the present machines, the power drive affords a constant speed movement at the standard testing rate of 0.100 in. per min. under full load or approximately 3 in. per min. under zero to moderate loads as may be required for initial positioning of the loading head. This power drive is reversible and is operated by foot-pedal control. Hand-wheel operation under full load at any speed from approximately 0 to 1 in. per min. is also available for special testing and other purposes.

Vertical travel of the column and loading head is indicated by a counter on the instrument panel which reads to 0.001 in. Overtravel in either direction is prevented by limit switches which either cut the power-drive circuit or flash a warning light during manual operation.

Vertical-load measurement is indicated by a large, extremely sensitive Bourdon pressure gage connected to the loading head. This gage is calibrated to read total load directly in pounds. At a pressure of approximately 100 psi. on the diaphragm, the present machines will deliver maximum vertical load of 2750 lb. The machines are constructed, however, for vertical loading to 4000 lb., if desired, and hence more indicated capacity could be obtained by a different selection of air gage and by increased pressure.

The "calibration" of the gage eliminates the necessity of calculating load by multiplying line pressure by effective diaphragm area. At first, some doubts were entertained as to the reliability and permanence of such a calibration, it being surmised that diaphragm replacement might well invalidate any individual calibration. Experience has fortunately dispelled these doubts. Several diaphragm replacements have been made for various development purposes in each machine, the replacements being in some cases new material of the same type as the original and in other cases a considerably different type of material. In no case has the calibration as checked against platform scales and proving rings showed an appreciable variation.

Load indication on the present machines is to the nearest 10 lb., with estimated readings to 5 lb. being possible

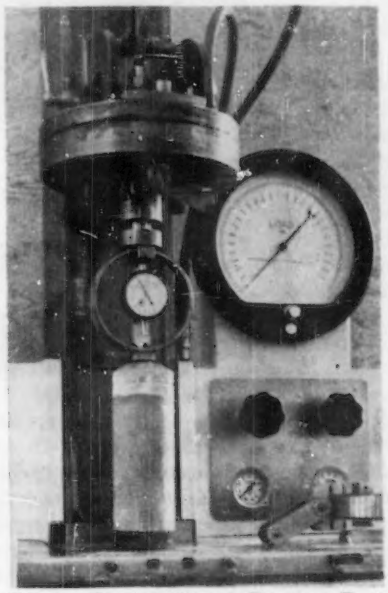
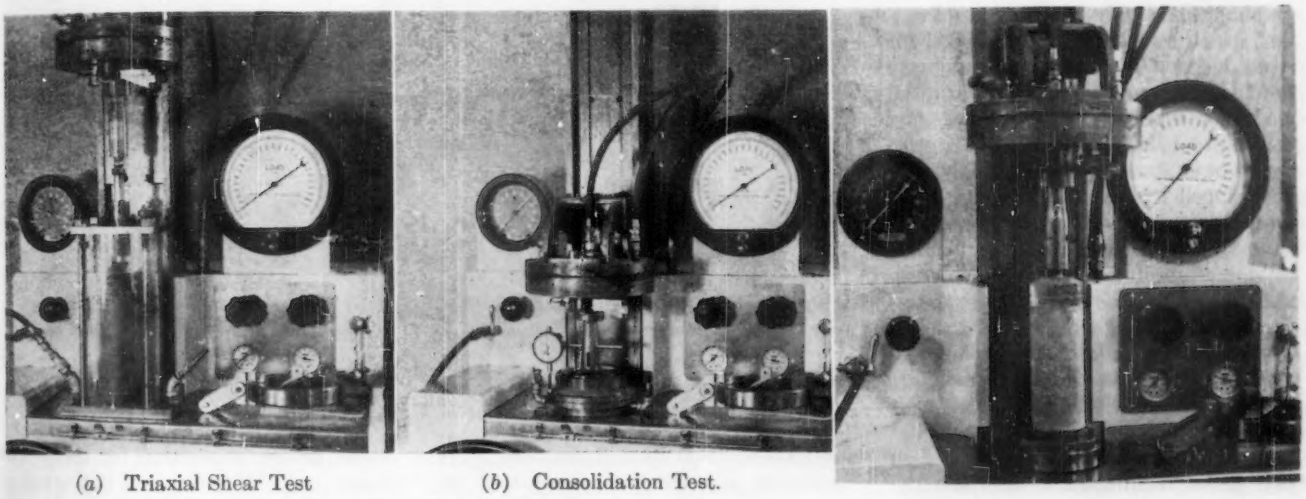


Fig. 4.—Proving Ring as Pressure Foot.



(*a*) Triaxial Shear Test (*b*) Consolidation Test. (*c*) Unconfined Compression Test

Fig. 3.—Use of Working Table.

ing downward through the housing. The pressure foot is guided by an essentially frictionless, longitudinal ball bearing making it possible to calculate load exerted on test specimens simply as the product of air pressure and effective diaphragm area.

Specimens or testing devices to be loaded are placed on the stainless steel working table under the loading head as shown in Fig. 3 in which an unconfined cylindrical soil specimen, a triaxial shear device, and a consolidometer are respectively illustrated as they appear during test. The working table has no vertical motion and serves in these tests merely as a nonsensitive base or support for the test piece.

The loading head is attached to a vertical column by cantilever brackets

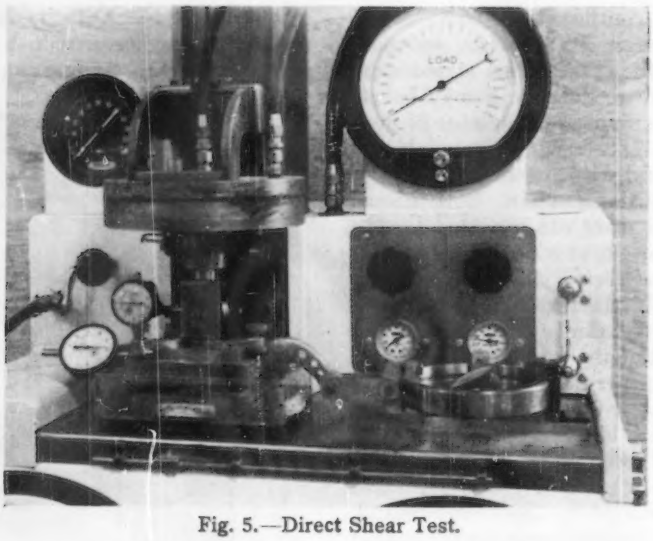


Fig. 5.—Direct Shear Test.

with considerable accuracy. With diaphragm at mid-position, an accuracy of approximately 2 per cent of scale reading can be obtained and at diaphragm positions ±0.025 in. from center, the accuracy is 4 per cent of scale or better. Diaphragm movement in this latter amount would only be experienced in a test which must be left unattended for many hours. When extremely accurate readings are required during the initial stages of a test, a light proving ring reading to 1 lb., may be used as a pressure foot as shown in Fig. 4. If the ring is equipped with a strut to prevent excessive deformation, the test may be continued after the ring capacity is reached by operation of the loading machine in the usual manner. No delay or interruption in loading is required to shift from proving-ring load measurement to load indication on the main weighing system of the machine.

The above-described construction and operation of the loading head is based on two major requirements, of which the first is to simulate dead weight loading, that is, loading which will remain constant (without manual or servomechanism control) while the specimen undergoes appreciable axial shortening. In this respect it duplicates the action of the various beam type or platform scale machines which are capable of "following" specimen deformation. In fact, the unit described herein can "follow" without adjustment and without significant loss of accuracy, a deformation of 0.050 in. rather than the 0.020-in. deformation which is the usual limit of platform scale machines. This accounts for the use of a pneumatically actuated flexible diaphragm as a means of applying pressure since at any constantly maintained air pressure the diaphragm will deliver an essentially constant load through the attached vertical pressure foot despite movement of ±0.025 in. from its mid-position. Very accurate maintenance of constant air pressure can be accomplished by use of coarse and fine diaphragm-type regulating valves connected "in series."

This same construction is also well adapted to the second loading requirement, namely, controlled variation of vertical loading from zero to full-scale magnitude. For testing of this nature, compressed air is bled into the loading head through a manually operated needle valve (instead of a regulating valve) at exactly the rate required to keep the floating diaphragm in mid-position while the loading head is moved steadily downward by the vertical screw mechanism. In certain tests of this type, there is a tendency, at failure, for the diaphragm to be overbalanced and to plunge suddenly to the bottom of its permissible travel, just as the beam would suddenly drop in a beam machine when sample resistance abruptly diminishes. This tendency has been completely overcome, however, by installing a bleeder valve in the diaphragm itself so that as the diaphragm moves even fractionally below mid-position, the pressure is automatically reduced and equilibrium is maintained. The operation of this device has been found to be superior to manual operation even by an experienced operator. It has, in fact, been found possible, as approximate maximum load is reached, to set the needle valve to deliver a slight excess of air and therefore to abandon manual control entirely, leaving the operator free to record data and observe specimen behavior.

The horizontal loading system, intended primarily for transverse shear testing, has several unique features as illustrated in Fig. 5 which shows a direct

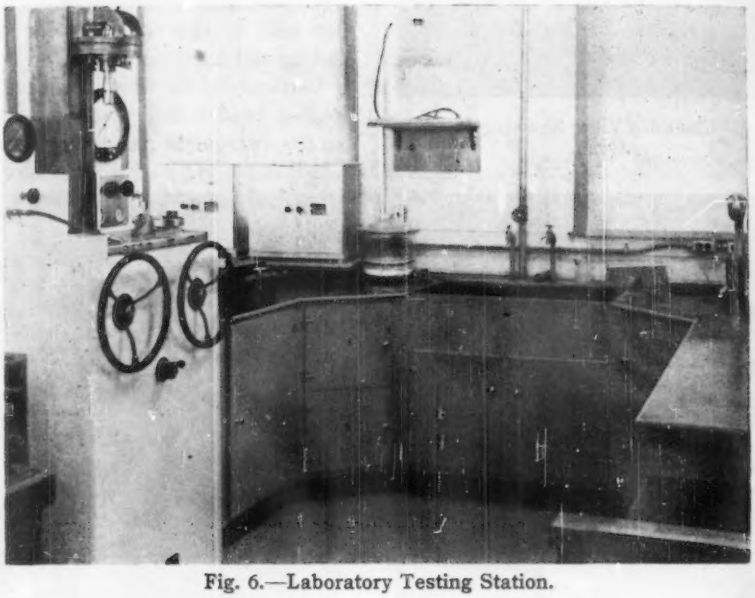


Fig. 6.—Laboratory Testing Station.

shear device in position for test. The lower part of the shear box in this operation is doweled to the working table, the latter being capable of being moved horizontally by a mechanical screw jack under full vertical loading. The conventional yoke attachment to the upper part of the shear box is linked to a proving ring for horizontal load measurement. In this test, the vertical loading system described above is employed to apply the load to the upper block which provides the normal stress on the plane of shear. For reasons which are given below, the vertical load is applied through a pressure foot with ball-bearing roller.

In many machines developed for this type of test, the line of action of the vertical loading becomes more and more eccentric as shearing displacement proceeds, since provision is made for movement of only one part of the shear box. To overcome this difficulty in the new

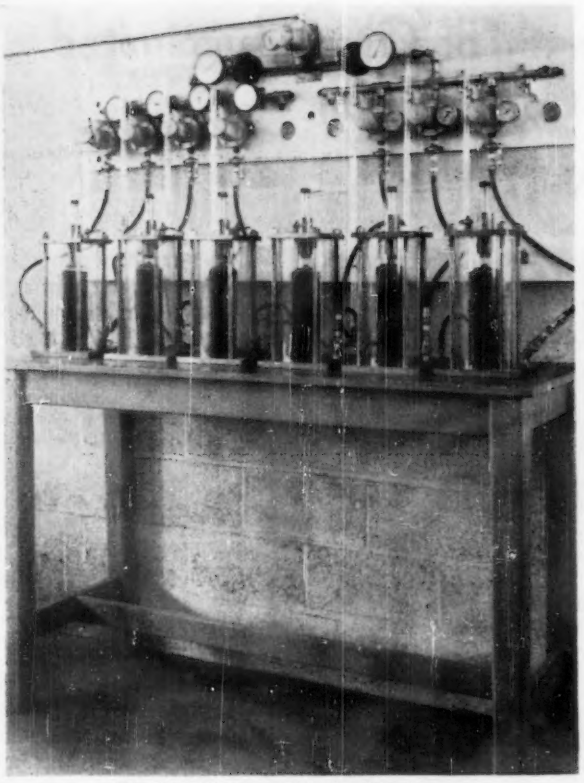


Fig. 7.—Preconsolidation Equipment.

machine, both upper and lower parts of the shear box are moved simultaneously at the same rate of speed in opposite directions, while the line of action of the vertical loading is fixed. Thus the vertical load is always delivered over the exact center of the remaining area of contact between upper and lower parts of the specimen. This eliminates objectionable tipping of the upper block and the resultant nonuniform stress distribution across the specimen. The above-described two-way movement is produced by having the working table and the proving ring horn both actuated by a single, longitudinal lead screw with right- and left-hand threads respectively engaging the table and the horn.

The horizontal drive is motorized for standard testing to give a relative motion under full load of 0.050 in. per min. of the two parts of the shear specimen. It can also be manually operated at any desired speed up to approximately 0.500 in. per min.

Direct or transverse shear tests may be conducted in the new machine according to methods developed for beam or dead weight loading machines or, if desired, with new and possibly superior techniques. The older procedure involves applying and maintaining a constant total vertical load on the top block of the shear box as the horizontal load is gradually exerted. A constant vertical load may be established and maintained simply by setting the regulating valve to furnish the desired loading. Thereafter, the sample may expand or contract vertically during shear, but, due to the flexible diaphragm in the loading head, the load is maintained constant without further attention by the operator. The vertical loading, on the other hand, may be varied during test if desired for reasons such as those discussed below, and it is in this respect that the new machine is superior to most platform scale machines in which load variation during test is usually inconvenient.

One reason for varying the total vertical loading on a transverse shear test is to compensate for the change in contact area in the specimen. By steady reduction of total loading in proportion to decrease of area, a constant vertical stress may be maintained. For some purposes this is more desirable than the steadily increasing stress which is produced during shearing displacement, when the total vertical load is constant. Secondly, under the many special requirements of research testing, even greater variation of load and vertical stress is often necessary.

Extensive variation of vertical loading on transverse shear tests has been essential in a recently completed research upon the effect of initial density of cohesionless soils on internal friction. During the initial stages of a test on a dense sample the upper block moves both horizontally and upward, the resultant movement being along an inclined plane. The maintenance of a constant vertical stress during this period does not produce a constant normal stress on the actual shear plane, a considerable variation of vertical stress being actually required for this purpose. Variation of vertical stress is also required for similar reasons in tests on initially loose specimens. In either case, it proved to be possible for a single operator to control the vertical loading as desired and also to take all necessary readings of proving ring and vertical extensometers. It is believed that further applications will be found for this facility once its availability is realized.

The universal loading machine described above was developed by collaboration between the author and Jerome A. Fried of the Ithaca Scientific Instrument Co. of Ithaca, N. Y., to meet the special equipment requirements for the newly established soils engineering laboratory at Cornell University. The basic organizational plan of this laboratory is a division of the testing facilities for student exercises into a number of similarly equipped bays in order to permit simultaneous and independent performance of scheduled tests by several groups. A single universal type loading machine for each bay is an essential requirement in this plan. The machine described herein is well adapted to such an installation as is shown in Fig. 6 and has proved to be very satisfactory for student operation as well as staff and student research.

Experience gained during lengthy test programs for research purposes indicates that the loading machine is also well adapted to production testing. In such work, the loading machine may be reserved exclusively for testing, and auxiliary equipment may be employed for the time-consuming process of preconsolidation. Figure 7 illustrates an apparatus for applying and maintaining any desired lateral pressure on triaxial test specimens prior to shear testing. This apparatus, like the loading machine, is pneumatically operated and thus provides further utilization of the centrally located air compressor. The preconsolidation pressure in the devices is maintained as the devices are transferred to the loading machine.

Three of the above-described machines are currently in use at Cornell, one with 10,000-lb. and two with 4000-lb. vertical loading capacity. Procurement of additional machines is contemplated to complete the testing facilities for undergraduate instruction.

Studies of the Strength of Glued Laminated Wood Construction[1]

By Alan D. Freas[2]

SYNOPSIS

The studies discussed herein were initiated at the U. S. Forest Products Laboratory in 1934 to produce data on the relations between the strength properties of glued laminated structural members and the factors affecting the strength of such members with a view to the establishment of recommendations for design procedures.

The initial program of research dealt primarily with curved members. The effects of such factors as curvature, end joints in laminations, defects, and methods of applying gluing pressure were studied. During the recent World War, the limitations of available data were recognized and a program of tests on beams and columns was begun. More extensive and detailed tests of the effects of end joints and knots than made in the previous program were included. In addition, the effects of these factors on compression members were studied.

The data from the two research programs have been used in the formulation of recommendations for procedures in the design of glued laminated structural members.

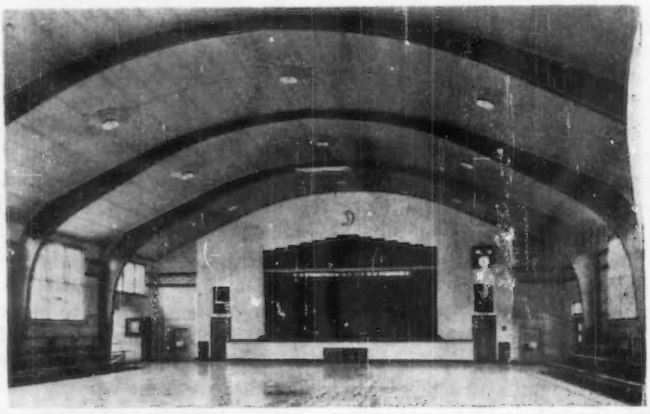
GLUED laminated construction has had a long history in Europe, particularly in Germany, Sweden, and Switzerland. A wide variety of applications were observed by a member of the Forest Products Laboratory staff during a European trip in 1936. During this trip he inspected some 50 structures varying in age up to about 30 years. From observations of members laminated with casein glue and used in buildings in which normal atmospheric conditions prevail, he concluded that the "lack of examples of members that have failed or have seriously deteriorated under such exposure during the third of a century of the history of this type of construction precludes any but optimistic estimates of length of life and permanence.[3]

The Laboratory staff member reported, further, that the observed good condition of locomotive repair shops and storage buildings and of chemical plants indicated that casein-glued laminated construction had had good resistance to coal and chemical fumes. From his observations of outdoor structures such as footbridges and railway-platform structures, he concluded that excellent performance could be expected from casein-glued laminated members in outdoor structures, provided that they were built so that drainage and ventilation would cause the rapid run-off and evaporation of moisture.

The use of glued laminated construction in the United States is much more recent. Although glued construction has been under development and has been used for some years in the United States, the extensive development of laminated construction began in the late thirties following the development of water-resistant glues and their successful application in other fields and the initiation of a comprehensive research program on the strength and design features of glued laminated arches at the Forest Products Laboratory. At about the same time a glued laminated arch building was constructed at the Laboratory. Since that time, however, the number and variety of applications have grown remarkably, and a new industry has resulted.

Examples of Application:

The Forest Products Laboratory building has 46-ft.-span arches of variable depth, tapering in both directions from a maximum at the knee, which was placed at eave height. This arrangement, with an approximately vertical leg, permits maximum utilization of space up to eave height. Arches of this type are suitable for gymnasiums (Fig. 1(*a*)) and industrial buildings, since they provide unobstructed floor area usable to a considerable height.



(*a*) Laminated arches of 63-ft. span in high-school gymnasium at Darlington, Wis.

(*b*) Laminated arches of various spans and shapes for theater at Los Angeles, Calif.

Fig. 1.—Laminated Arches.

An unusual application of glued laminated arches is illustrated in Fig. 1(*b*). This structure employs a number of

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[1] This paper was presented at the Session on Wood held at the First Pacific Area National Meeting of the Society, San Francisco, Calif., October 10–14, 1949.

[2] Engineer, Forest Products Laboratory, Forest Service, U. S. Dept. of Agriculture, Madison, Wis.

[3] T. R. C. Wilson, "The Glued Laminated Wooden Arch," *Technical Bulletin 691*, U. S. Dept. of Agriculture (1939).

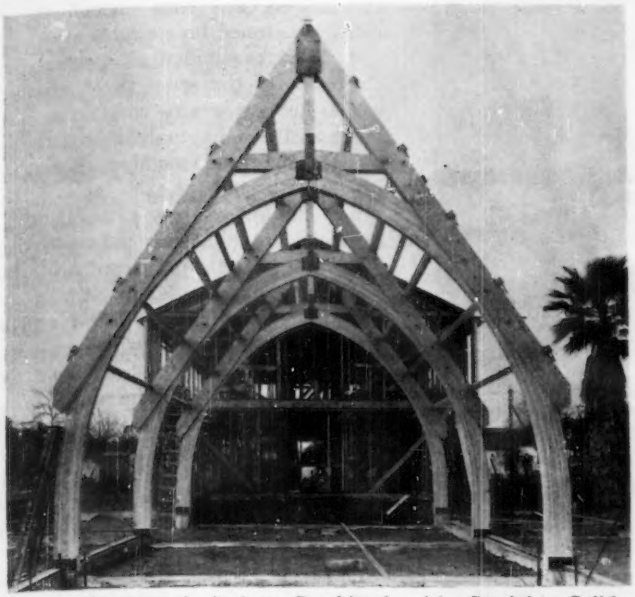


Fig. 2.—Laminated Arches Combined with Straight, Solid Members for Architectural Effect in Church at San Gabriel, Calif.

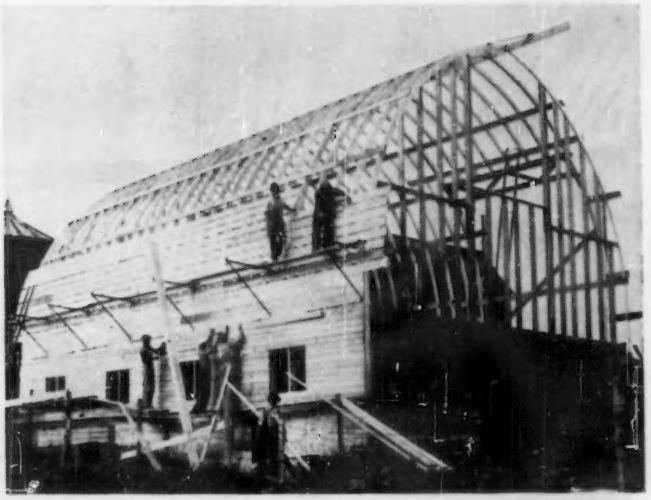


Fig. 3.—Laminated Barn Rafters (1⅝ by 5½ in. in Cross-Section) Continuous from Foundation to Peak. Spacing of Rafters, 2 ft.

arches differing in form and span in order to provide a cone shape for more efficient motion-picture projection.

Glued laminated arches have found considerable acceptance in church construction. The pleasing and traditional architectural effects possible are illustrated in Fig. 2.

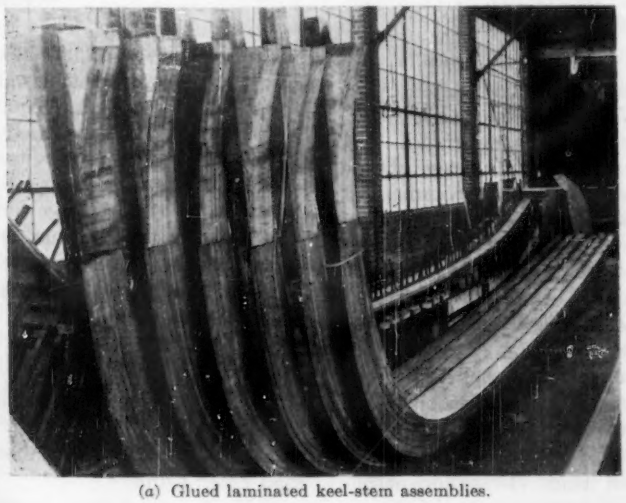
Curved glued laminated rafters are being used in farm structures to an increasing extent, particularly in barns (Fig. 3). The rafters, ordinarily of relatively small size and spaced about 2 ft. are now available in a number of stock sizes at lumber yards and farm cooperatives. Members of this same general character are used also in small one-story industrial and commercial buildings.

Military use accounted for a large volume of glued laminated construction during the recent World War. Not only was it employed in many types of military buildings, such as drill halls and aircraft hangars but also for other military uses, such as wooden vessels and wooden aircraft. During the War, the shortage of white oak of proper quality and adequate size for keels, stems, frames, and other parts led to an intensive program of research as to the feasibility of the employment of glued laminated parts in wooden vessels. Illustrative of the applications are the keel-stem assemblies shown in Fig. 4(*a*), which demonstrated adequate durability and considerably improved strength and stiffness as compared to their mechanically joined counterparts, and the bilge planking (Fig. 4(*b*)) formed with compound curvature and twist, which simplified assembly. Not to be forgotten for their largely unpublicized part in the War, are the laminated spars, spar flanges, and other structural parts of the thousands of trainer, cargo, and glider aircraft that saw service.

One of the more common applications of glued laminated wood is in the upper chords of bowstring trusses. Commonly, lower chords and web members are solid rather than laminated. In the trusses shown in Fig. 5, however, not only are both chords laminated, but the side- and end-wall posts as well.

Glued laminated structures in exterior applications are not common. The railroads of this country are taking an increasing interest in the possibilities of laminated construction. This interest has been evidenced by the installation of a number of experimental bridges. One such installation, involving laminated stringers, posts, and caps, is shown in Fig. 6.

Illustrative of the large sizes and



(*a*) Glued laminated keel-stem assemblies.

(*b*) Laminated boat-bilge planking formed to a pattern of compound curvature and twist.

Fig. 4.—Laminated Construction in Boat Building.

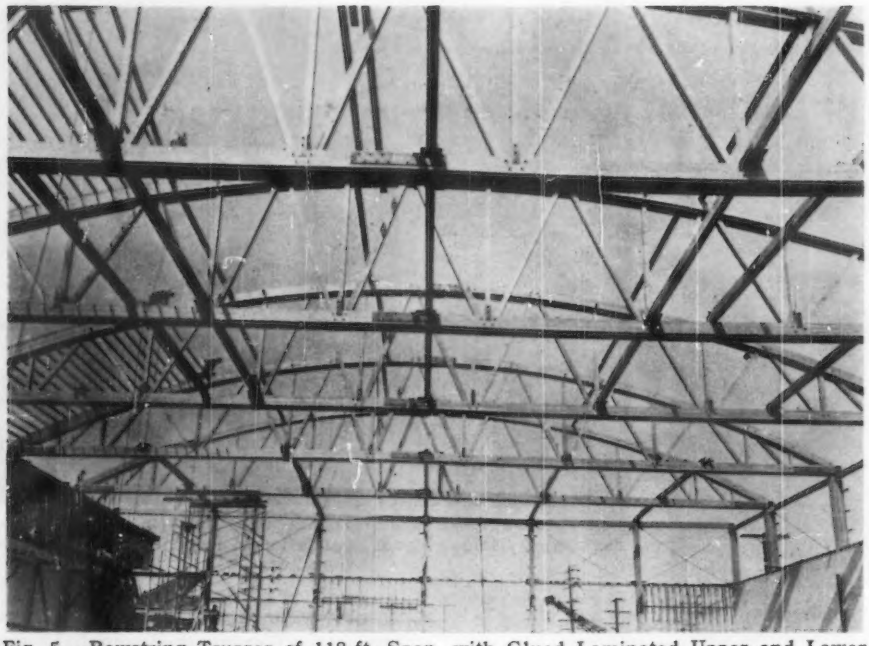


Fig. 5.—Bowstring Trusses of 118-ft. Span, with Glued Laminated Upper and Lower Chords, for Sound Stage of Movie Set at Hollywood, Calif. Side- and end-wall posts also of glued laminated construction.

Fig. 6.—Railway Trestle of Laminated Southern Yellow Pine Timbers, Whose Stringers, Posts, and Caps Were Glued with Intermediate-Temperature-Setting, Phenol-Resin Glue, and Pressure Treated with Creosote.

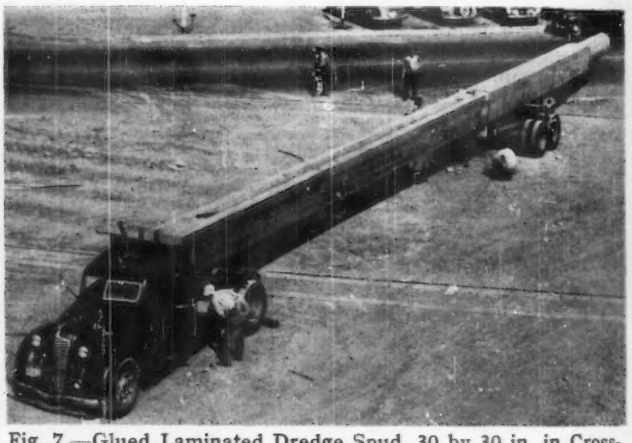


Fig. 7.—Glued Laminated Dredge Spud, 30 by 30 in. in Cross-Section and 85 ft. Long.

exacting uses possible with glued laminated construction is the 30 by 30-in. by 85-ft. dredge spud shown in Fig. 7. A number of such spuds have had extensive use in dredging work on the Columbia River.

A somewhat unusual application of simple beams is found in the roof supports of a dye house in Portland, Ore. The highly humid, acid atmosphere existing within the building precluded the use of steel girders or trusses, or even of timber trusses with steel bolts or connectors, to span the 80-ft. building because of the certainty of rapid corrosion. Thus a wood beam laminated with a resorcinol glue highly resistant to these exposure conditions provided a practical solution to a problem.

Advantages of Glued Laminated Construction

Advantages of glued laminated wood construction are many and significant. They include the following:

1. Ease of fabricating large structural elements from standard commercial sizes of lumber. Laminated arches have already been erected that provide buildings with clear spans up to 170 ft. as have laminated beams of 80-ft. span. Arches with sections as deep as 7 ft. have been projected.

2. Achievement of excellent architectural effects, and the possibility of individualistic interior decorative styling.

3. Freedom from checks or other seasoning defects associated with large one-piece wood members, in that the laminations are thin enough to be readily seasoned before fabrication.

4. The possibility of designing on the basis of the strength of seasoned wood, for dry service conditions, inasmuch as the individual laminations can be dried to provide members thoroughly seasoned throughout.

5. The opportunity to design structural elements that vary in cross-section along the length in accordance with strength requirements.

6. The possible use of lower-grade material for less highly stressed laminations without adversely affecting the structural integrity of the member.

7. The fabrication of large laminated structural members from smaller pieces is increasingly adaptable to future timber economy, when more lumber will come in smaller sizes and lower grades from smaller trees.

On the other hand, there appear to be no disadvantages of laminated construction as such. Modern glues and gluing techniques provide both adequate and effective means of bonding laminations into an assembly equal or superior in strength to a single-piece member of equivalent section. They may be selected to provide a laminated assembly that is water-resistant or waterproof as conditions of use may dictate. When properly glued, laminated members may be given preservative treatment by pressure methods much as solid members are treated and thereby have greater resistance to decay when used under adverse exposure conditions.

There are, however, certain factors involved in the production of laminated timbers not encountered in producing solid timbers. A number of these are:

(*a*) The preparation of lumber for gluing and laminating usually raises the cost of the final product above that of solid green timbers.

(*b*) For constructions in which green timbers are satisfactory, more time is

required to cut and season lumber and to laminate the timber than is required to cut solid green timbers.

(*c*) Since the value of a laminated product depends upon the strength of the glue joints, the laminating process requires special additional equipment, plant facilities, and fabricating skill not required for producing solid green timbers.

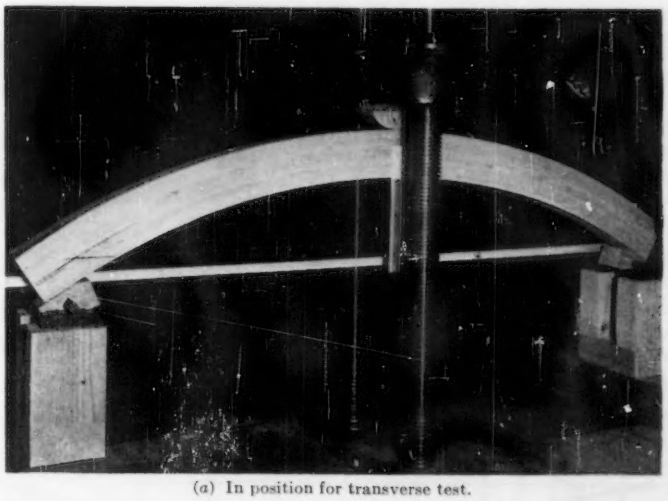
(*d*) Since considerably more operations are involved in manufacturing laminated members than in manufacturing solid members, there are more possibilities for error, and special care must be exercised in each operation to insure a product of high quality.

(*e*) Large curved members are difficult to ship by common conveyances.

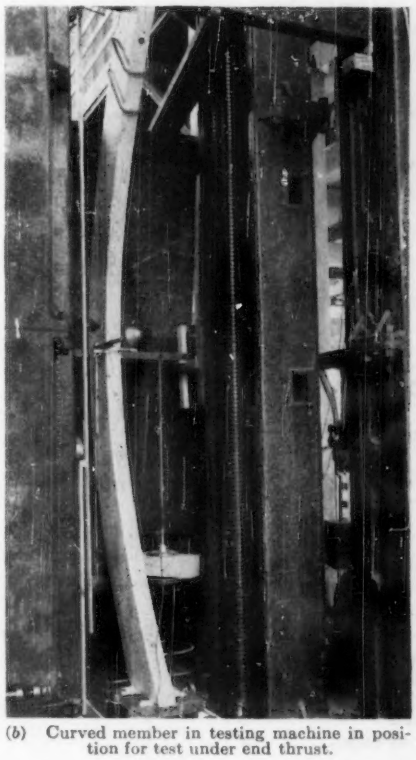
Background of Testing

The first research at the Forest Products Laboratory on the strength properties of glued laminated construction was begun in 1934 on curved members. This research, which covered a period of several years, studied a number of factors affecting strength including curvature, end joints, and defects. It culminated, in 1939, with a publication of the U. S. Department of Agriculture.[3] This bulletin not only presented the results of an extensive series of tests, but presented also recommendations on working stresses and design procedures. It has had extensive use, since its publication, as a basis for design and specification of this type of construction.

During the War, it became increasingly apparent that additional research was necessary to answer the questions that arose with the development of this method of construction. Accordingly, with the cooperation of the War Production Board and industry, further work was undertaken at the Forest Products Laboratory, including the testing of a large number of full-size beams and columns to provide additional design data and information for technical phases of specifications. Factors investigated included the relative strength of members containing end joints of different types, the effect on strength of defects in different laminations, the effect of varying the thickness of laminations, and like factors. The results of this work and of the previous study on arches have been correlated with other available information and have been incorporated in a manuscript giving Forest Products Laboratory recommendations on working stresses and methods of design of glued laminated structural members. These recommendations are to be combined with Laboratory recommendations on fabrication techniques[4] and they will then



(*a*) In position for transverse test.



(*b*) Curved member in testing machine in position for test under end thrust.

(*c*) Half-arch D-1 in position in machine with scales for reading horizontal deflections at several points.

Fig. 8.—Curved Member in Testing Machine.

be published on a U. S. Department of Agriculture technical bulletin that will constitute a comprehensive presentation of information on glued laminated structures.

While this paper has for its major purpose the presentation of information on the strength testing and design of glued laminated material, its author would be remiss if he did not at least mention the developments in glues and gluing techniques that have made this material so promising for the future. Prior to the War, casein glue was the only adhesive that was reasonably practical for use in structural members. Its limitations under severe exposure were recognized, and Wilson stated in 1939 that "glues made from synthetic resins and urea are much more resistant to moisture and to fungus attack than are casein glues. These types are being increasingly used in the manufacture of plywood. For the most part, high temperatures are required for setting them and they are consequently not, in general, economically usable for building up large members. Further developments that will render them applicable are to be expected. Such developments, together with advances in methods of excluding moisture and in gluing material treated for resistance to fire, insect, and fungus attack, may be expected to increase the durability of glued laminated construction and to extend the field of its applicability."[3]

The expectations expressed above

[4] A. C. Knauss and M. L. Selbo, "The Laminating of Structural Wood Products by Gluing," *Report No. D1635*, Forest Products Lab. (1948).

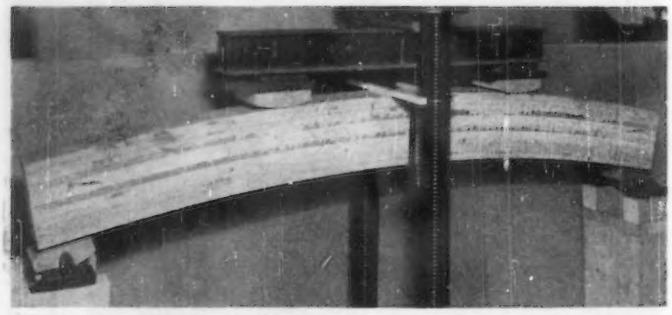


Fig. 9.—Curved Laminated Member in Machine in Position for Longitudinal-Shear Test Under Transverse Load.

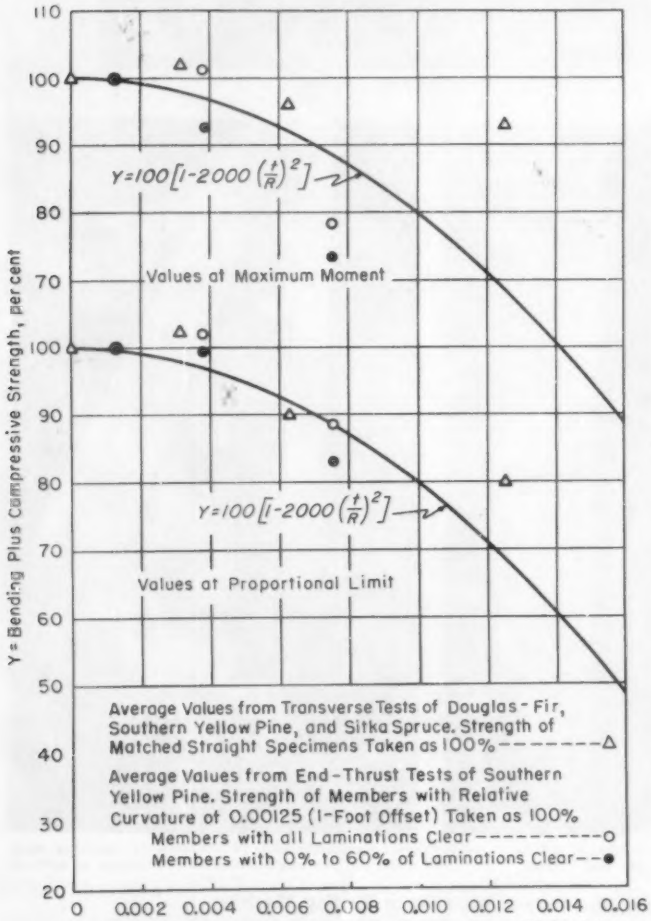


Fig. 10.—Strength of Laminated Members as Related to Curvature.

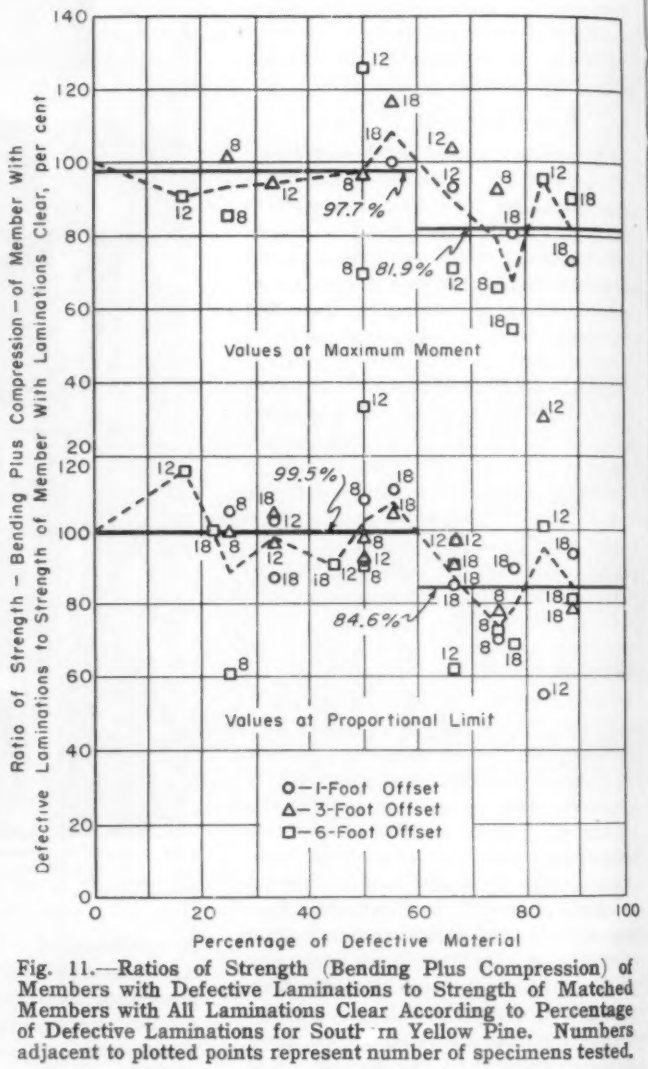


Fig. 11.—Ratios of Strength (Bending Plus Compression) of Members with Defective Laminations to Strength of Matched Members with All Laminations Clear According to Percentage of Defective Laminations for Southern Yellow Pine. Numbers adjacent to plotted points represent number of specimens tested.

were fulfilled during the War when a number of synthetic resin adhesives capable of being set at room or intermediate temperatures (between room temperature and about 200 F.) were developed by the adhesive industry. Coincident with these developments, the Forest Products Laboratory pursued an active and continuous program of research on the properties of these adhesives and on the techniques of applying them for optimum results. This research has resulted in an authoritative guide to the selection and use of adhesives for laminating, which is available in preliminary form as Forest Products Laboratory Report No. D1635[4] and which as previously mentioned, is to be incorporated in a U. S. Department of Agriculture technical bulletin.

In cooperation with the Research and Marketing Administration, the Laboratory recently carried out an investigation of on-the-job methods of fabricating curved laminated member suitable for such uses as brooder houses and machine sheds, and of the strengths of members made by these methods as compared with the strengths of members made by conventional methods.

Tests of Curved Members

Methods of Test:

A few tests of curved members were made under transverse bending (Fig. 8(*a*)) to investigate the effect of initial stress. The majority of the tests, however, were made under end thrust, both on laboratory-made specimens (Fig. 8(*b*)), which constituted the major number of specimens, and on a few full-size building arches (Fig. 8(*c*)). Load, lateral deflection at the center of the length, and change in length of the chord were observed simultaneously in tests of laboratory-made specimens. In the tests of building arches, load, lateral deflection at several points along the length, and chord shortening were measured simultaneously. In addition, measurements of longitudinal strain over a short gage length (2 in.) were made at several points.

In tests to compare the shear strength

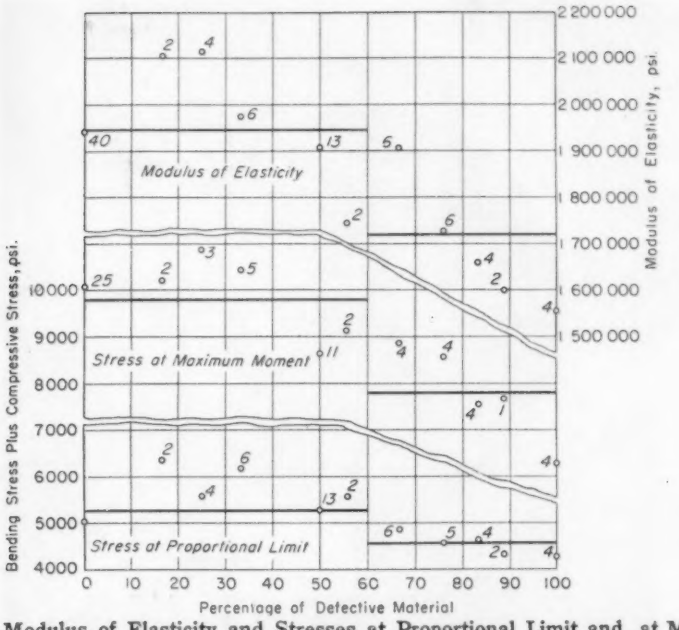


Fig. 12.—Modulus of Elasticity and Stresses at Proportional Limit and at Maximum Moment for Southern Yellow Pine Members with Various Percentages of Defective Material. Numbers adjacent to plotted points represent number of specimens tested.

of members in which gluing pressure was applied by nailing or by clamping, transverse bending was employed (Fig. 9) as well as standard glue block-shear tests. A brief study of tensile strength perpendicular to grain employed sharply curved U-shaped laminated specimens tested by pulling the ends apart so as to create tensile stresses perpendicular to grain in the curved portion of the specimen. These tests were supplemented by standard tension-perpendicular-to-grain tests on minor specimens cut from the larger specimens after failure.

Effect of Curvature:

It was recognized that, in bending laminations to curved form, stresses are set up, the magnitude of which depends upon the relation between the thickness of the lamination and the radius to which it is bent. To evaluate the effect of this factor in reducing the strength of laminated members, specimens having various ratios of lamination radius to lamination thickness were tested either in transverse bending (Fig. 8(*a*)) or under end thrust (Fig. 8(*b*)).

The results are summarized in Fig. 10, where the strengths of bent members are shown on a percentage basis. Both transverse and end-thrust tests are represented. The curves shown represent the average effect of curvature on modulus of rupture and fiber stress at proportional limit. The factor representing the strength of a curved member as compared with that of a comparable straight member is

$$1 - 2000\,(t/R)^2$$

where:

t = lamination thickness and
R = radius to which the lamination is bent.

The strength reduction indicated by the formula above is considerably less than would be expected from a consideration of the magnitude of the stresses induced by bending the laminations. For example, bending to a radius 160 times the thickness produces stresses approximately one-half the ultimate and about equal to the proportional limit. Stresses at this level would be expected to cause severe reductions in strength. The fact that these severe reductions are not found from tests indicates that the stresses induced in bending the laminations to form are relieved to a considerable extent.

The data indicated that modulus of elasticity is not affected by curvature.[3]

Effect of Defects:

A number of arches were made with varying proportions of clear and of defective material, of which the defective material occupied the central portion of the member and the clear material the outside portions. These arches were matched with others that consisted entirely of clear material. The matching was achieved by ripping 12-in.-wide clear boards into two equal pieces, one of which was used in the outer portion of one assembly and the other in the same position in another. The central portion consisted of 6-in.-wide clear boards in one assembly and 6-in.-wide defective boards in the other. The "defective" material consisted of typical No. 2 Common southern yellow pine.

The results from the tests of matched pairs of specimens are shown in Fig. 11, where the results for arches containing defective material are shown as ratios to the values for the matched member consisting entirely of clear laminations.

Considering the spread in strength values among members consisting entirely of clear material, it was concluded that up to 60 per cent of defective material in the central portion of a laminated member does not significantly reduce the strength below that of members consisting entirely of clear laminations. Members with less than 60 per cent defective material averaged 99.5 per cent as high in proportional limit values and 97.7 per cent as high in values at maximum moment as the all-clear members with which they were matched. Corresponding ratios for members with more than 60 per cent defective material were 84.6 and 81.9 per cent.

Additional data were available from tests of members containing various proportions of defective material, but with which all-clear specimens had not been paired. Figure 12 shows all available data. Here again, only moderately lowered strength values are indicated for members having up to about 60 per cent of defective material as compared to members having all laminations clear.

Effect of End Joints:

Available lengths of lumber are frequently not adequate to provide full-length laminations for the larger structures. It is necessary, therefore, to join two or more lengths of lumber end to end to provide the necessary lamination lengths.

Obviously, butt joints without glue have no strength in tension, and tests have shown that when glued they are very erratic in strength, and that with even the best technique in using available glues they attain no more than a fraction of the tensile strength of the wood. Further, even with the best techniques in fitting, butt joints can be expected to be only partially effective in transmitting compressive stress.

In curved laminations, butt joints are additionally undesirable because of their effects on interlamination contacts in their vicinity. It is impossible to produce curvature right to the end of a square-ended piece; hence, in the vicinity of butt joints, contact between adjacent laminations can result only from pressure sufficient to crush the wood and expel the glue, which makes the joints between laminations locally deficient in resistance to shear.

Tests have indicated, however, that a scarfed joint, if carefully prepared, well glued, and of sufficiently flat slope, can have a considerable proportion of the strength of an uncut piece.

Specimens having end joints (glued scarf, unglued scarf, and butt) in various locations and combinations were matched with specimens having all laminations continuous. The results from these tests were rather erratic. From these data, however, it was concluded that glued scarf joints having a slope of 1 in 12, and reasonably well separated in adjacent laminations, will result in members whose strength, particularly at porportional limit, will not be significantly lower than that of members with all laminations continuous. It was concluded also that such joints at the same point in the length of successive laminations are undesirable.

Tests of Radial Tension:

Theoretical considerations indicate that radial stresses occur when a curved member is subjected to forces that tend to change its radius of curvature. When the forces are such as to increase this radius, these stresses are tension. The radial tensile stress that could be expected in an actual curved member loaded in this manner was checked by means of a few special tests according to the method shown in Fig. 13. Minor specimens from these members and from two straight members were tested in tension perpendicular to grain by standard methods.

All curved specimens failed in radial tension. The values of radial tensile stress at failure were quite erratic, due probably to certain deficiencies in the gluing techniques and in making the specimens.

In general, the radial tensile stresses at failure were on the order of one-half to two-thirds the values obtained from minor specimens tested in tension perpendicular to grain by the standard method. The data were very limited and were confined to a single species, so that it was obvious that they could not serve as a basis for establishing design values for this property. They did, however, serve to provide a limited check on a proposed method of establishing design values.

Gluing Pressure Obtained by Nailing:

The use of nailing as a substitute for clamping pressure, if adequate results could be obtained, would offer certain advantages. It would both simplify and cheapen this type of construction and would permit members to be built at or near the building site, so that the production of members too large for convenient transportation over long distances would be possible.

The possibilities of nailing were explored in a preliminary way in two series of tests. The first consisted of block-shear tests on specimens cut from straight members to which gluing pressure had been applied by nailing or by clamping. An equal number of specimens was glued by each method. In the second series, matched pairs of curved members—with one of each pair nail-glued, the other clamp-glued—were tested in transverse bending so arranged as to cause failure by longitudinal shear (Fig. 9).

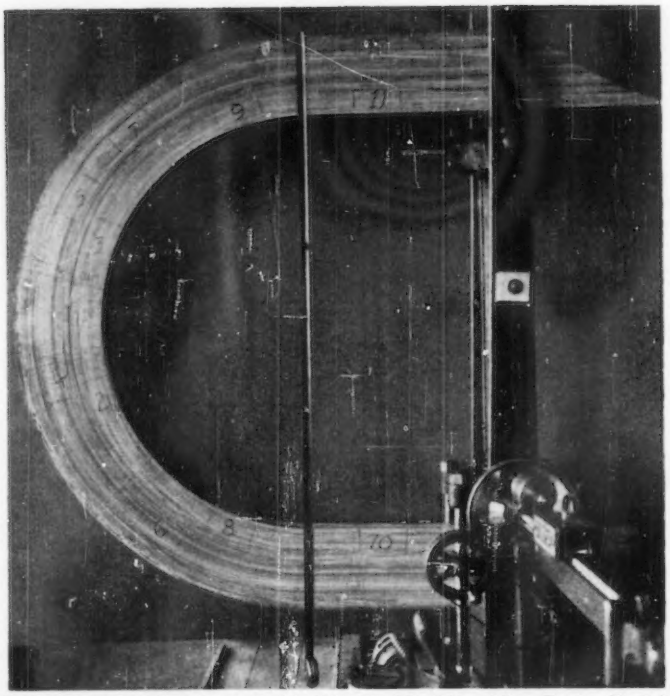


Fig. 13.—Radial-Tension Specimen in Position in Machine After Test. Test is made by pulling ends of specimen apart. Note circumferential cracks where tension failure has occurred.

The block-shear tests indicated considerably lower average shear values for the nailed than for the clamped members, with the values averaging 68 per cent for the southern pine and 78 per cent for the Douglas fir. Further the variability was considerably greater. Three of the four comparisons from the transverse-bending tests showed lower values for the nailed than for the clamped specimens, with the values ranging from about $\frac{3}{4}$ to about equal. Percentage of wood failure, too, was considerably lower for the nailed specimens.

From the data so obtained, it was considered unlikely that as strong and dependable glued joints could be obtained by nailing as by clamping except, perhaps, by the use of so many nails that the procedure would be uneconomical. It was recognized, however, that structures could be designed in which the required shear resistance would be low. Further, it may sometimes be economical to increase the size of members so as to make up for the lower shear resistance of joints in nailed members and thus to provide for glued laminated construction under circumstances such that clamping during assembly is not feasible or where members are too large to be transported to the building site following assembly by clamping. The durability of joints made by gluing pressure obtained with nails is unknown.

The data indicate, however, that even with the rather close nailing used in the assemblies tested, the allowable stress in longitudinal shear for nail-glued assemblies should be no more than about two-thirds that permitted for clamped assemblies. The essential similarity between results from shear blocks containing nails and from those not containing nails adds emphasis to the recommendation that mechanical fastenings, such as nails, cannot be expected to supplement the strength of a glued joint.

Comparison with Other Types of Curved Members:

Two types of members have had considerable use in farm structures. One consists of laminations bent to form and nailed without gluing; the other, commonly called the segmental rafter, is made by band-sawing the edges of boards to the required curvature, assembling the boards, which must be in comparatively short lengths, and nailing them together with the necessary butt joints staggered in adjacent layers. In this type, the laminations are vertical instead of being bent to follow the curvature. A few tests were made to

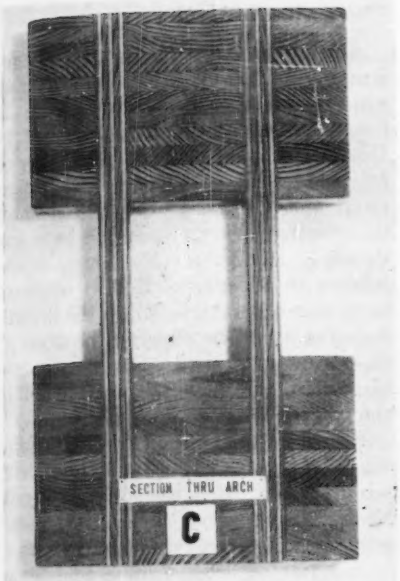


Fig. 14.—Cross-Section of One Arch of Each of Types C and D, as Used in the Forest Products Laboratory Service Building.

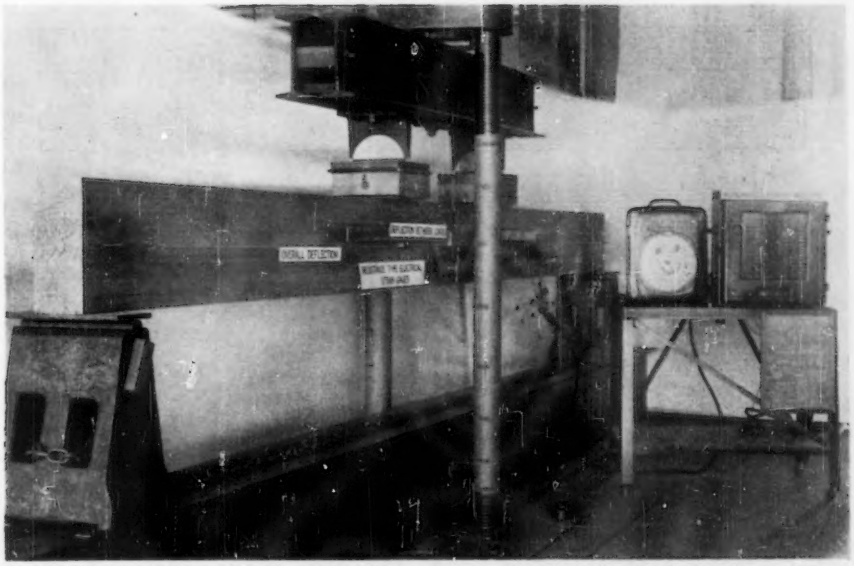


Fig. 15.—Typical Setup of a Beam Ready for Test. Electrical Strain Gages Shown Were Used on Only Part of the Beams.

afford a means of comparison between these types and those made of laminations bent to form and glued.

Tests indicated a definite superiority of glued laminated over nailed laminated members. The nailed type showed no proportional limit and no maximum load, and the test was discontinued when deflection became excessive. Even so, such final loads were on the order of only one-quarter to one-half the maximum loads sustained by the glued specimens. Deflections at final load for the nailed members were from two to five times as large as deflections at maximum load for the glued members.

The segmental type, however, gave a somewhat better comparison. The stiffness of the segmental members (measured by the ratio of moment to deflection at proportional limit) was comparable to that of the glued members. Maximum load was on the order of one-half as large, but supplementary tests with the vertical laminations nail-glued gave maximum loads nearly as high for the segmental as for the bent members.

A lack of lateral stiffness was exhibited by the nailed segmental member. It appeared, however, that maximum load was but little affected by this lateral bending. Further, in service such buckling is often restrained by roof sheathing or other parts.

Tests of Building Arches:

At the time the arches for the Laboratory building were procured, two full-size half arches of each type (Fig. 14) were obtained for test. All were tested under end-thrust loading as indicated in Fig. 8(*c*). No general conclusions can be drawn from the test data, but it may be of some interest to review briefly the character of the failures.

The first D-type (Fig. 14) arch was tested in its full length. Although initial failure occurred at the knee, final failure occurred in tension at a point farther up the length. Considerably higher load would have been sustained had the full strength of the knee been developed. Before testing the second arch of this type, about 11 ft. were cut off the upper end to encourage failure in the knee and thus to get a measure of the strength of the most severely curved portion. Unfortunately, this specimen failed in longitudinal shear.

In the C-type arches (Fig. 14) failure in both cases resulted from separation of plies of the plywood web at the outer portion of the knee and subsequent lateral buckling of the flanges. In one test, clamps were arranged to restrain this lateral buckling, and the reinforcing action of these clamps probably caused the greater maximum load to be sustained.

Tests of Building Arches in Place:

The central arch of the Laboratory building was loaded with bags of sand and gravel placed on the roof directly above the central arch. The load was placed in increments, the final total of which was some 42 per cent in excess of the design live load. Deflections at the peak and quarter-points of the central and other arches were read after placement of each increment of load and from time to time between increments and over the period of several months during which the total load remained on the arch.

A plot of the summation of immediate deflections of the peak of the central arch indicated an approximately linear relation between load and peak deflection up to and including the final load. While deflection increased considerably during the approximately five months the total load remained on the structure, the effects of moisture change during this period are such that it is impossible to determine whether increased deflection was caused by the load.

It may be interesting to note the effect of the roof construction of this building on the deflection of the central arch above which the load was applied and on the distribution of this load to other arches. The roof consisted of panels 16 ft. long, 4 ft. wide, and slightly more than 6 in. deep, made up of plywood sheets glued to the tops and bottoms of 2 by 6-in. joists at the center and at the edges of the panels. Outer faces of the edge joists were grooved to receive splines holding faces of adjacent panels in alignment. The lower plywood sheet of each panel was nailed at each end to the upper face of the arch on which it rested, and the 2 by 6-in. joists were toenailed to the arches.

The roof panels, being nailed to the arches and being very stiff edgewise, transmitted the spreading of the loaded arch to adjacent arches and thus caused deflections of these arches at their

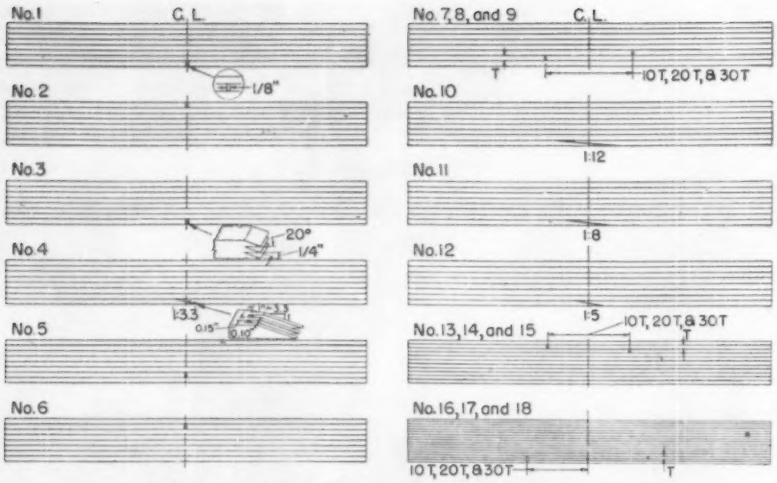


Fig. 16.—Jointing Patterns for Laminated Beams.

Patterns Nos. 1, 2, 5, and 6 are butt joints in single laminations. Patterns Nos. 7 to 9 and 13 through 18 are butt joints in more than one lamination, with various spacings between joints in adjacent laminations. Pattern No. 3 is an Onsrud joint. Pattern No. 4 is a serrated scarf joint. Patterns Nos. 10 to 12 are scarf joints of various slopes in single laminations.

peaks. A study of the peak deflection of the five central arches (the loaded arch and two to each side) indicates that the action of the roof construction was such as to distribute nearly a third of the load to adjacent arches. This brings attention to the fact that roof panels of this type, if sufficiently resistant to shearing forces acting in their plane, may have a significant effect in distributing concentrated or nonuniformly distributed loads, or moving loads such as might be carried by a crane.

Tests of Beams and Columns

Methods of Test:

All beams were tested under two-point loading (Fig. 15). The original plan was to load all beams at the quarter-points of the span, but a disproportionate number of shear failures was found in early tests and, in most subsequent tests, the loads were moved toward the center as far as the spacing of knots or joints would permit.

Simultaneous readings of load and central deflection were made to failure. In addition, strains in regions surrounding joints, along critical laminations, and on critical cross-sections were obtained with resistance-type electrical strain gages for one beam from each group of three having a common jointing pattern.

In testing the columns in end compression, 1-in. Tuckerman strain gages were mounted at the middle of the two opposite faces formed by the edges of the laminations. In addition, on one column of each group of three having a common jointing pattern, resistance-type electrical strain gages were used to obtain strains in the regions surrounding each joint and along critical laminations.

Shear Stresses in Beams:

Amoung the Douglas fir beams tested, a number failed in longitudinal shear at rather low values of shearing stress. It has been previously recognized that in Douglas fir there is sometimes a layer of unusually weak cells located in the material first formed at the beginning of the growing season. Such cells have low shearing strength. Numerous shear failures that occurred in this series of tests were observed to follow the growth rings, as would be expected in wood of this character, and microscopic examination showed that failure had occurred in the layer of cells first formed.

Following this, a second set of beams was made up of laminations from a different region, with the idea that, perhaps, the weakness mentioned occurs only in certain localities. This group of beams was tested in such a manner as

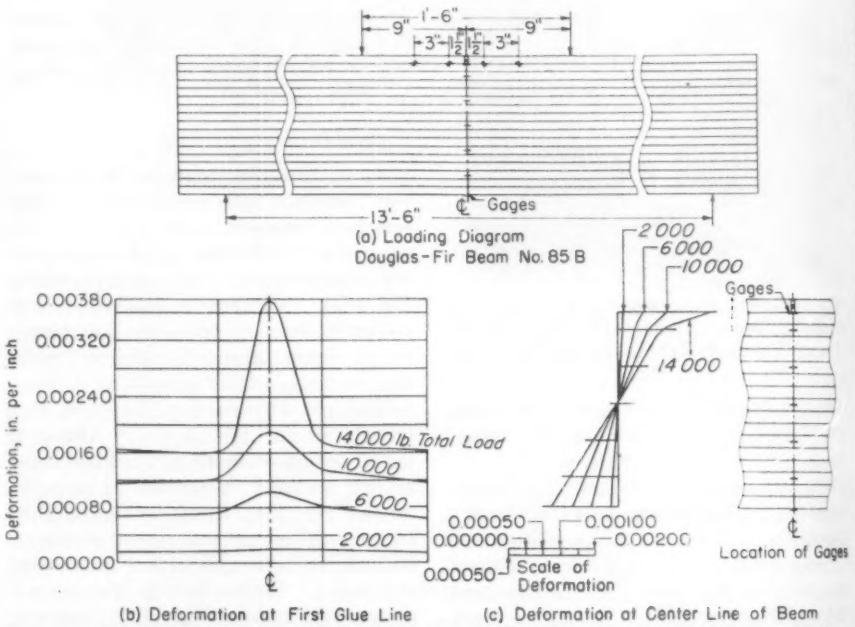


Fig. 17.—Distribution of Longitudinal Strains in Douglas-Fir Beam (Jointing Pattern No. 2).

Effect of Lamination Thickness:

One group of Douglas fir beams was essentially free of knots and served as a control for other groups of beams. The beams of each group were all approximately 6 in. in depth, but the groups were made from 8, 11, or 17 laminations. They served, therefore, to answer the question of whether the strength properties of a horizontally laminated beam are influenced by the thickness or number of laminations. Results from some 85 beams approximately equally divided among the three groups (8, 11, or 17 laminations) were such as to indicate no significant differences among the three groups. They were, accordingly, grouped together.

to encourage failure by shear. From those that failed in this manner, the average shear stress at failure was about 25 per cent higher, with the minimum value approximately equal to the maximum value from the first group.

Among a third group of vertically laminated beams, those that failed by shear gave a still higher range of values, with the minimum for this group being approximately equal to the maximum from the second group.

These data indicate that the weakness mentioned is more prevalent in some localities than in others. The fact that, in the last group, the plane of shear failure was radial, whereas in the others it was tangential, indicates the possi-

bility that radial shear strength is higher than tangential. This is only partially confirmed by shear tests of small clear specimens.

Knots apparently do not have a serious deleterious effect on shear strength, since a comparison of shear strengths from tests of clear and knotty beams gives essentially the same average value and range.

Beams with Joints:

Figure 16 illustrates the types and spacing of joints in the beams tested.

Data from electrical strain gages for values of load below the proportional limit showed that in every instance the variation of strains on a cross-section is essentially linear, except in the immediate vicinity of a joint, and that the point of zero strain is at or very near the midheight of the beam. These two facts indicate that, under working loads, the deflection of the beam and the general stress distribution are determined by the properties of the full cross-section, with the joint acting as a stress raiser to cause local variations in stress. These conclusions are substantiated by photoelastic studies and by mathematical analysis. The mathematical analysis shows that the neutral plane of a beam containing a hole moves away from the hole only a small fraction of the distance by which the gravity axis is shifted.

This is illustrated by Fig. 17, in which are shown strain measurements on a beam containing a butt joint in the top lamination. The strain in the region of the joint was found to reach a measured value about $2\frac{1}{4}$ times as great as the strain at the same vertical position in a cross-section that was at some distance from the joint and subjected to the same moment. This is consistent with mathematical investigations that show that, in a beam of orthotropic material, the intensity of stress at the extremities of the major axis of an elliptical hole having a ratio of major to minor axes of 50 and with the major axis perpendicular to the direction of principal stress, is some 240 per cent as great as the stress at some distance from the hole. The mathematically investigated case is somewhat analogous to a butt joint in a lamination.

The longitudinal tension or compression stress in a butt-jointed lamination is, of course, zero immediately adjacent to the joint and increases by transfer through shear from the adjacent laminations as the distance from the joint increases. Hence the excess of longitudinal stress in the continuous laminations over that in the jointed ones is a maximum at the joint, and, consequently, the shear stress is a maximum at the joint, where it is very concentrated. The result is that shear failure starts adjacent to the joint and progresses as more of the length of the jointed lamination is relieved of its longitudinal stress. Progressive failure of this character was observed in the tests of beams containing butt joints.

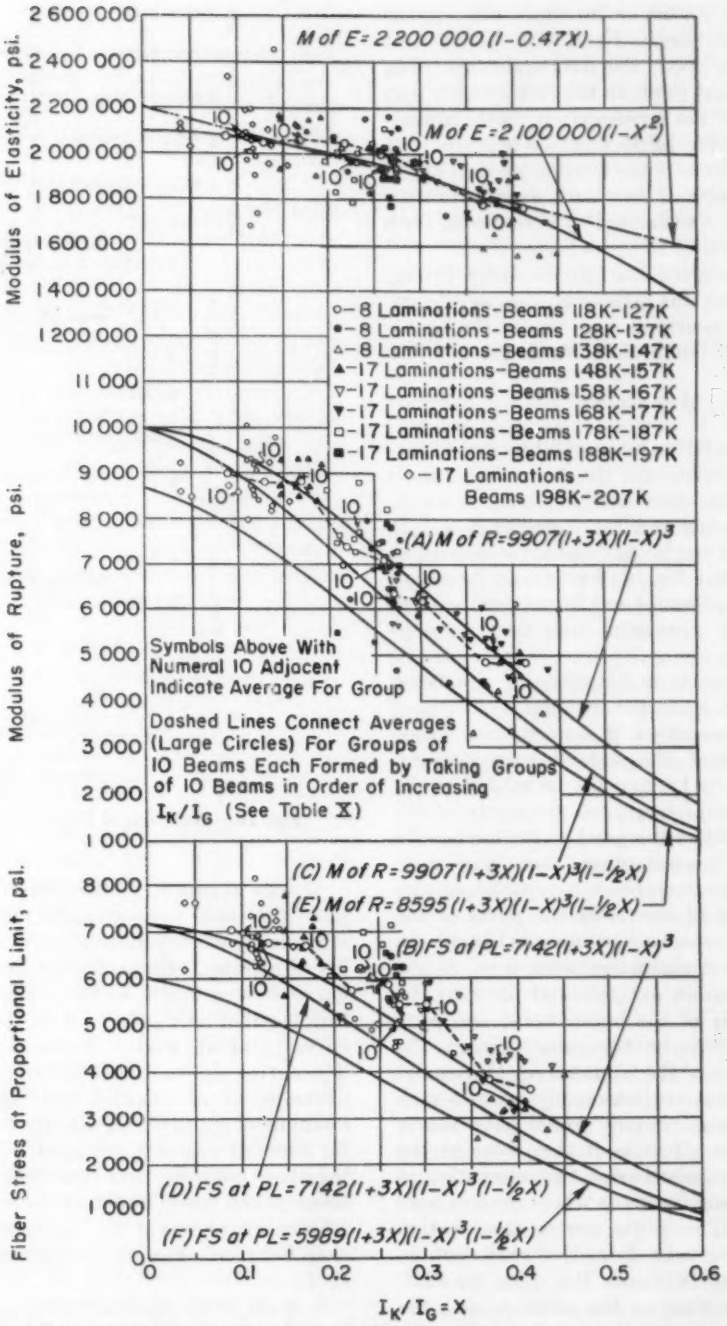


Fig. 18.—Variation of Strength Properties of Horizontally Laminated Douglas-Fir Beams with Knots with the Ratio I_K/I_G.

Butt joints, therefore, not only concentrate longitudinal stress in the unjointed laminations but concentrate shear stress at the joint and start shear failures. They are undesirable, therefore, not only because they fail to transmit longitudinal stress, and therefore represent an ineffective area in the beam, but also because they are serious stress raisers.

The data from beams containing butt joints were somewhat erratic, but indicated, for joints in the compression portions of the beams, strengths essentially conforming to that which would be expected if the lamination containing the joint were considered to be ineffective. Joints in the tension portions of the beam, however, reduce strength somewhat more than would be estimated by considering the joint ineffective.

In some tests, the beams contained butt joints in adjacent laminations

spaced 10, 20, or 30 times the lamination thickness. Even with the greatest spacing used, the data indicated that, with butt joints in the compression portion of the cross-section, both laminations were ineffective. When the butt joints were in the tension portion of the cross-section, the results were lower than would be estimated by considering both laminations to be ineffective.

Among the scarf joints shown in Fig. 16, there was little to choose, as all gave values nearly as high as did the beams with all laminations continuous.

Beams with Knots:

Some 90 beams were fabricated to permit correlation of the strengths of beams with the sizes and positions of knots. The beams were fabricated of Nos. 1, 2, and 3 Douglas fir boards (as defined in *Rule Book No. 12*, West Coast Bureau of Lumber Grades and Inspection) so as to provide a range in knot size and position.

Inasmuch as the strength of a beam depends upon the moment of inertia of its cross-section, it seemed valid to assume that the reduction in strength caused by knots could be related to the moment of inertia of the parts of the cross-section occupied by the knots. To test this assumption, there was computed for each beam a value of I_K, the moment of inertia of the parts of the critical cross-section occupied by knots. The knot diameters were used in the computation as measured prior to the assembly of the laminations, and were assumed to be the same through the thickness of the lamination. Obviously, knots that are reasonably near to each other longitudinally would have nearly the same effect as if they were at the same cross-section. Consequently, in computing I_K, knots whose centers were within 12 in. of the central cross-section were assumed to be at that cross-section.

Figure 18 shows the data for each beam plotted as the ordinate and the corresponding value of I_K as the abscissa, with I_K being expressed in terms of I_G, the gross moment of inertia of the cross section. In addition, there are plotted averages for 9 groups of 10 beams, each formed by arranging the beams in order of increasing values of I_K/I_G and taking the first 10 as a group, and so on.

The material for the control beams and for the knotty beams came from the same general region and, further, had essentially the same average specific gravity. Therefore it seemed proper that the curves representing the relation of fiber stress at proportional limit and modulus of rupture to I_K/I_G should pass through the average values for the control beams.

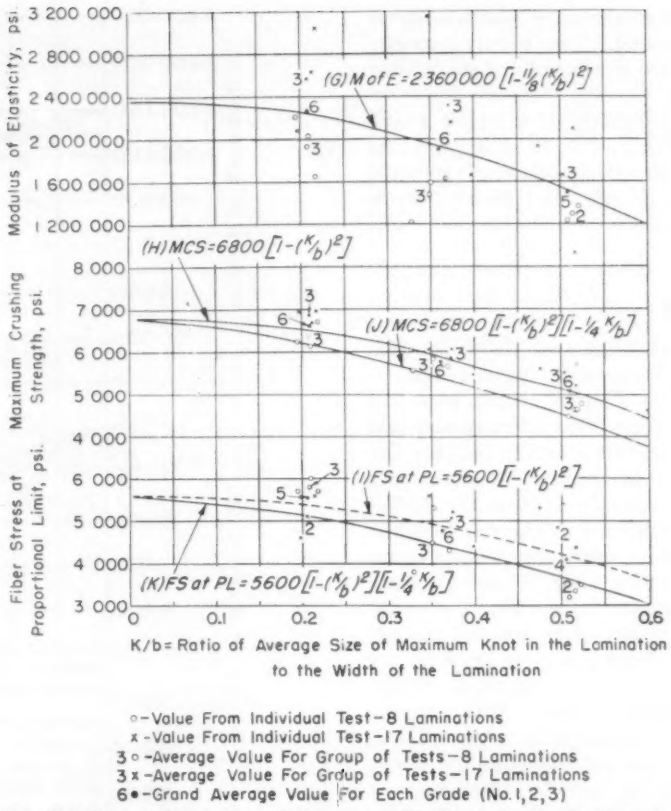


Fig. 19.—Relation of Properties of Columns with Knots in Laminations to K/b.

It was assumed, further, that knots have the same proportionate effect on stress at proportional limit as on modulus of rupture. Hence the ordinates of curve B were made to be in the same ratio to that at $I_K/I_G = 0$ as those of curve A at all values of the abscissa. The curves shown do not fit the plotted averages, being slightly too high for modulus of rupture and slightly too low for stress at proportional limit. Taken together, however, and considering the assumptions made in fitting them, they reasonably represent the average relation between strength properties and I_K/I_G.

A study of the data indicated that, as I_K/I_G increased, the variance in strength properties increased. Assuming that the variance in the strength of clear wood remains constant, it appears that there is a variance in the effect of knots and that this latter variance increases with increase in I_K/I_G. A study of this effect led to a factor by which to depress the average curve to take account of the variance in knot effect. Curves C and D represent average curves depressed by application of this factor. Application of this curve to the minimum value from the control beams gives curves E and F. It may be noted that all but a few of the test points are above these latter curves. They are, therefore, considered suitable as a basis of design.

Subsequent to the completion of the tests discussed above, inspection of some narrow laminated rafters disclosed concentrations of knots the full width of the raters. Computations indicated the strength reductions caused by such knots to be extremely large, and it was deemed desirable to see whether the properties of members containing such concentrations were in accord with the results discussed above.

Accordingly, two sets of beams, each containing 10 laminations, were tested. One set contained knots the full width of the top and bottom laminations, with all other laminations clear. The second set contained knots the full width of the laminations in all but the top and bottom laminations. In all cases, the knots were placed at the central cross-section.

The beams containing knots in all but the top and bottom laminations gave results slightly higher than would be predicted by curves A and B of Fig. 18, but were in reasonable agreement. The other set, however, did not conform at all.

In the second set, the knots in top and bottom laminations can carry but little stress. They fail early, and the maximum loads sustained by the beam, therefore, represent the load carried by the inner clear laminations. When the test data were considered on this basis, they gave results in agreement with matched beams having all laminations clear. This fact indicates that, for such

a case, the outer laminations should be considered totally ineffective and that the strength should be computed on the basis of a beam whose size is that corresponding to the clear laminations.

This consideration immediately led to the question of the proper treatment of a beam containing knots in the outer laminations nearly, but not quite, the full width of the lamination. Theoretical analysis indicated that the knot size equivalent in its effect to a knot the full width of the lamination varied from two thirds the lamination width for a beam containing many laminations to nearly the full width for one containing few laminations. For the case under consideration, it appears that, for all practical purposes, a knot larger than two thirds the lamination width should be treated as though it occupied the full width.

In tests of single-piece beams, it has been difficult to differentiate between clear and knotty beams with respect to modulus of elasticity. The data of Fig. 18, however, show a definite decrease of modulus of elasticity with increasing I_K/I_G. The modulus of elasticity as computed from the loads and deflections recorded during test represent the integrated effect of strains throughout the length of the beam and, unlike strength values, might not be expected to correlate well with a value of I_K/I_G computed from the characteristics of a short length. The correlation with values of I_K/I_G so computed probably results from the fact that the general character of a lamination that contains knots is somewhat the same throughout and is reasonably well represented by the short portion of the length that was considered in computing I_K.

The linear regression represented by the dashed line of Fig. 18 indicates, for $I_K/I_G = 0$, a value of modulus of elasticity considerably higher than the average for the control beams. It could not, therefore, be considered to represent the effect of I_K/I_G. The curve represented by the solid line has been chosen as giving an acceptable representation.

Data from tests of some 15 vertically laminated beams failed to show a relation between strength and I_K/I_G. This lack may result from an insufficient range of I_K/I_G in the tests. Analysis of the data indicated, however, that the average strength ratio of the individual laminations, each computed in accordance with accepted methods for joist and plank,[5] is a reasonable estimate of the strength ratio of the laminated beam.

Columns with Joints:

A number of columns containing butt joints and scarf joints of various slopes were tested. Some specimens having butt joints in adjacent laminations and spaced 30 times the lamination thickness, were included.

The data showed, for columns with butt joints in the two outside laminations, that, on the basis of net area, stress was developed by the jointed specimens as high as that developed by the unjointed specimens. For columns with butt joints in the two outside laminations at the same level, and in the adjacent laminations at a level distant 30 times the lamination thickness, the stress at failure on the net section was less than for the unjointed specimens. From this fact it appears that an overlap of 30 times the lamination thickness is insufficient to transfer and distribute the load from jointed laminations.

The data for columns containing scarf joints indicated no deficiency in strength as compared to strength of unjointed specimens, even for scarf-joint slopes as steep as 1 in 3.

Columns with Knots:

In making up the columns for test, each lamination was selected so as to have at least one knot approximating a specified size, with this size being different for each of several groups of columns. These laminations were then arranged in such a way as to distribute the maximum knots longitudinally and to avoid concentrating them at or near any one cross-section.

The data are shown in Fig. 19, with the values of strength being plotted against K/b, where K is the average of the sizes of the largest knots in the laminations. In each plot the average values are very nearly in linear relation with K/b. Such straight lines, however, intersect the left-hand scale at values higher than would be expected of material of the same density but free of knots, and hence they cannot be considered representative.

Curves G, H, and I represent the parabolic curves best fitting the data. Curves H and I intersect the left-hand axis at values in reasonable agreement with those from clear specimens. Curve G, however, intersects at a value approximately 30 per cent higher than the average value found from tests of clear columns. No adequate explanation is available for this discrepancy.

The increased variance with increasing values of K/b is compensated by depressing the average curves to give curves J and K. The procedure used in deriving the required amount of depression was analogous to the procedure used in connection with the beam data.

Future Research

While the research discussed herein represents a considerable body of knowledge on the subject, which permits the designing of laminated structures with reasonable confidence, there still remain problems to be solved.

Subsequent to the research described earlier, the Forest Products Laboratory made additional studies on the spacing of end joints in laminations. The results, while affording useful information, were not conclusive. Further, the possible combinations of joints are myriad, presenting an endless array of possible tests if all were to be investigated. Some attempt should be made to develop a theory of joint action to simplify the problem.

It has long been known that deep beams develop, in test, lower stresses than do shallow beams, and that box or I-beams develop lower stresses than do beams of solid section. Two independent investigations of the effect of depth have developed two different expressions for depth effect, which vary considerably from each other. The maximum beam depth tested was 14 in. Yet beam or arch depths of 3 ft. are not uncommon, and an arch with a depth of 7 ft. has been projected. In designing at such depths the Laboratory is on uncertain ground. It needs, therefore, to investigate the effect of depth over a considerable range and to study the fundamentals of this phenomenon.

The weakness of some Douglas fir in shear has been mentioned earlier. If it were found that Douglas fir were markedly stronger in shear in the radial than in the tangential plane, it might be advantageous, for cases where shear strength requirements are high, to use laminations so cut that the plane of shear would be radial. The Laboratory proposes to study this problem and to investigate the possibilities.

The items mentioned above represent only a few of the more urgent problems still to be solved. There are many others.

[5] T. R. C. Wilson, "Guide to the Grading of Structural Timbers and the Determination of Working Stresses," *Miscellaneous Publication 185*, U. S. Dept. of Agriculture (1934).

Evaporation Rate of Hydrocarbons and Their Mixtures[1]

By L. S. Galstaun[2]

THIS paper reports on a study of the basic variables which affect the evaporation rate of hydrocarbon substances. The initial investigation was made on a wide series of pure hydrocarbons including straight and branched chain representatives of the aliphatics from normal pentane through 2,2,5-trimethylhexane, the aromatics benzene, toluene, *m*-xylene, *p*-xylene and the naphthenes cyclopentane, methyl cyclopentane, cyclohexane, and methyl cyclohexane.

The evaporation rate of any liquid is primarily an energy relationship. It is closely related to the rate at which heat is supplied to or absorbed by a liquid surface and that required for vaporization.

In turn the rate of supply of heat is dependent largely upon the following factors:

1. The difference of temperature of the liquid surface and the surrounding atmosphere (provided that there is no radiant heating source).
2. The total heat-absorbing surface exposed of both liquid and pan.
3. The thermal conductivity of the medium at the ambient temperature.
4. The apparent or "effective" film thickness at the ambient temperature and the velocity of the atmosphere above the liquid surface and on the bottom of the pan which contains the liquid.

Additionally, the humidity of the atmosphere may have some effect on the more volatile materials—when condensation of water occurs on the evaporating surface. Also affecting evaporation rate would be the rate of diffusion of the vapor into the atmosphere.

We have listed a number of possible variables and there may be more. But certainly if consistent data are to be obtained, some rather extensive measures of control are required in order to obtain conditions comparable in all major respects.

Apparatus

An evaporating chamber consisting of a horizontal pipe was designed with accessories to accomplish the following:

1. To control and maintain the air at a constant and controlled flow rate, temperature, and relative humidity.
2. To permit introduction of liquid samples onto the evaporating pans without opening the evaporating chamber or disturbing the condition inside.
3. To permit a continuous record of the unevaporated liquid on the pan.
4. To obtain a continuous record of the temperature of the evaporating liquid.

The particular assembly used in this work[3] is shown in Fig. 1.

Air is taken from the line at a pressure of 90 psi. and flows at this pressure through an air filter, a pressure-reducing valve and then to a rotameter where the air is metered. From the rotameter the air flows to a steam hydrator and then to a constant-temperature bath. In the constant-temperature bath the air is brought to fixed temperature which may be above or below that of the atmosphere. From the constant-temperature bath it enters the heating section of the evaporating chamber proper. This heating section contains an extensive grid of copper screens which act as an air distributor and also as a reservoir of heat with relatively high heat capacity to facilitate good temperature control. The air then enters the main evaporation chamber. This chamber is surrounded by a circulating water jacket maintained at the same temperature as the air to eliminate convection currents inside the chamber.

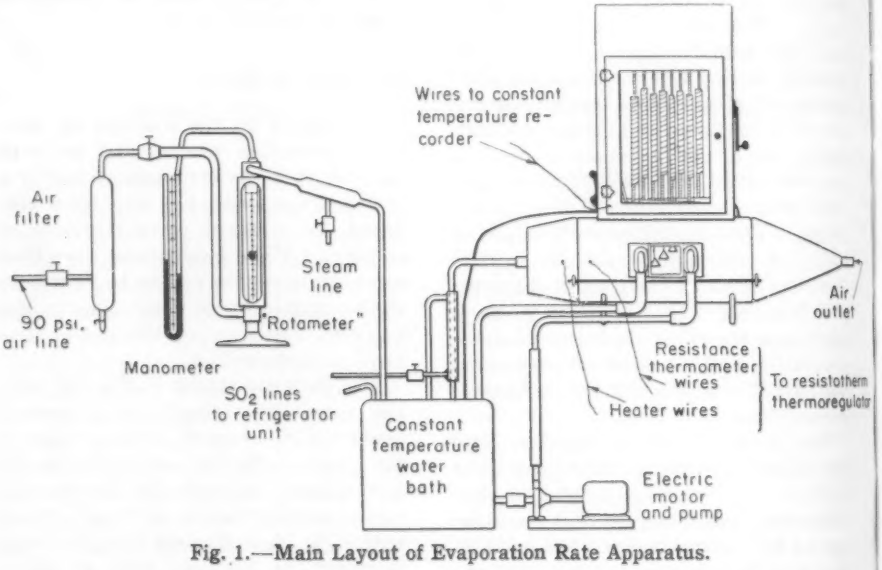


Fig. 1.—Main Layout of Evaporation Rate Apparatus.

Each of the evaporating pans is attached to a Jolly balance spring. This spring permits a recording of the weight of unevaporated liquid on each pan. The chamber is also arranged with a series of automatic pipettes which can be prefilled with a charge of liquid and then simultaneously discharged onto the pans at the time the experiment is started. At the time that the liquid is discharged, all of the pans are arrested and held at a fairly high level in the evaporating chamber, directly below the discharge of the pipettes. As soon as the liquid has dropped on the pans, the suspensions are released and the pans drop to their normal level. The height at which the pans are suspended

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NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] This paper was presented at the Session on Paint held at the First Pacific Area National Meeting of the Society, San Francisco, Calif., October 10–14, 1949.

[2] Research and Development Dept., Tide Water Associated Oil Co., Associated, Calif.

[3] Five figures showing some of the details of the apparatus have been omitted, but the information can be secured upon application to the author.

in the chamber increases in the direction of air flow so as to minimize mixing of vapors from one evaporating pan to the next. Since the vapors are heavier than air, the arrangement with the increasing height of the pan with the direction of air flow would tend to eliminate mixing of vapors above the evaporating liquid. The air is then expelled at the outlet.

This apparatus was originally intended to give evaporation rates on a series of hydrocarbons simultaneously. However, this turned out to be fairly impractical, because the temperature of the evaporating liquid was found to be an extremely important variable. By running the apparatus on one liquid at a time, it was possible to record evaporating temperatures from one pan while taking observations on the evaporation rate of the other.

Some important details with regard to the evaporating pans should be mentioned. The pans are made of 0.015-in. duraluminum sheets. They are 5.05 cm. in internal diameter and 0.25 cm. deep. A nylon thread of proper length connects the pan support to a wire crosshair. The upper end of the crosshair is connected to the Jolly balance spring. A centimeter scale behind the crosshair, provided with a mirror, permits Jolly balance reading free of parallax. A circular lens paper held down by a brass wire ring was placed in each pan. This was to insure as nearly as possible a constant surface area throughout the entire evaporation.

The Jolly balance springs used in this investigation have a sensitivity of about 5 cm. per g. All were calibrated before being used.

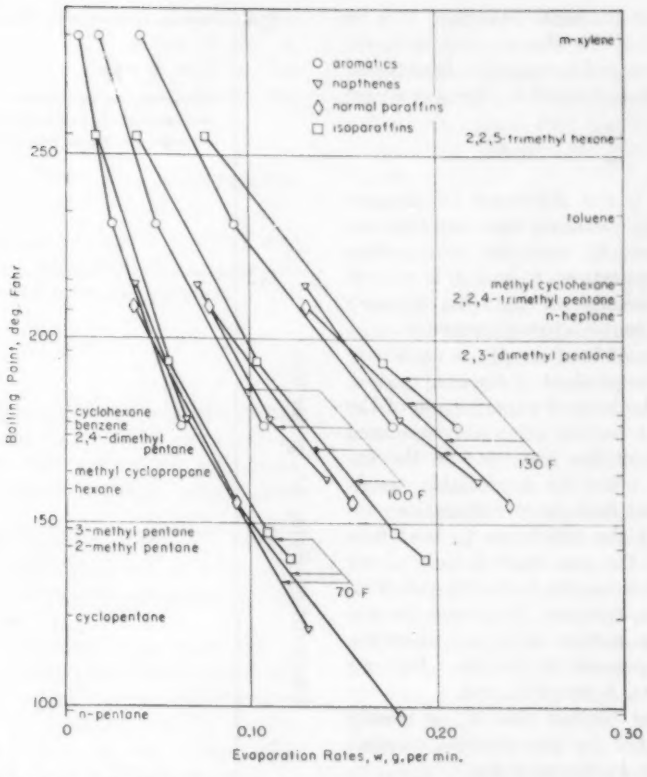


Fig. 2.—Correlation of Effect of Air Temperature, Chemical Structure of Hydrocarbon, Boiling Point, and Evaporation Rate.

Experiments conducted with air rate of 2.5 cm. per sec. at 70, 100, and 130 F.

TABLE I.—MATERIALS AND PROPERTIES[a]

Hydrocarbon Studied	Boiling Point, deg. Cent.	ΔH_{25} C., cal. per g.	Density at 25 C., g. per ml.
n-Pentane[b]	36.074	87.54	0.62139
2-Methyl pentane	60.271	82.83	0.64852
3-Methyl pentane	60.282	83.96	0.65977
2,2-Dimethyl butane	49.741	76.79	0.64446
n-Hexane	68.742	87.50	0.65482
2,4-Dimethyl pentane	80.500	78.44	0.66832
2,3-Dimethyl pentane	89.784	81.68	0.69091
n-Heptane	98.427	87.18	0.67951
2,2,4-Trimethyl pentane	99.238	73.50	0.68781
2,2,5-Trimethyl hexane	124.084	74.86	0.70322
Benzene	80.103	103.57	0.87368
Toluene	110.623	98.55	0.86231
m-Xylene	139.102	96.03	0.85990
p-Xylene	138.348	95.40	0.85669
Cyclopentane	49.262	97.22	0.74045
Methylcyclopentane	71.812	89.83	0.74394
Cyclohexane	80.738	93.81	0.77389
Methylcyclohexane	100.934	86.07	0.76506

[a] A.P.I. Project 44: "Selected Values of Properties of Hydrocarbons."
[b] Normal pentane was not studied at 100 or 130 F. since these temperatures are above its normal boiling point.

Test Conditions

Three standard temperatures were used, namely, 70, 100, and 130 F. Air rates in the evaporation chamber were standardized at 2.5, 5.0, and 7.5 cm. per sec. The air velocities are based on air at 70 F. and one atmosphere pressure. The air had a relative humidity of approximately 15 per cent at room temperature, and this was found to be substantially constant throughout this investigation. The variation in humidity was not attempted because we soon ran into difficulties with condensation of water on the surface of normal pentane when air of higher humidity was used. This has the drawback of making the evaporating rate measurements extremely erratic.

Development and Verification of an Equation for Evaporation Rate

Materials Studied:

The evaporation rate and the drop of liquid temperature were determined experimentally for the pure hydrocarbons listed in Table I.

Figure 2 shows the relation between the boiling points and the original data on evaporation rates, at 2.5 cm. per sec. and at temperatures of 70, 100, and 130 F., for the various solvents studied. It will be noted that for the same boiling point the increase of evaporation rate is in the order (1) aromatics, (2) normal paraffins and naphthenes, and (3) isoparaffins.

Relations Between Evaporation Rate and Temperature Drop:

The relationship among the variables of the problem can be correlated by the use of Fourier's law of thermal conductivity, which is as follows:

$$\frac{dQ}{d\theta} = -kA\,\frac{dt}{dL}$$

where:

$dQ/d\theta$ = time rate of heat flow,
A = area of section normal to the flow of heat,
dt/dL = temperature gradient in the direction of heat flow, and
k = thermal conductivity.

If it is assumed that dt/dL is constant throughout the heat transfer medium, the differential ratio can be replaced by

the over-all gradient. Further, if it be assumed that the thermal conductivity may be averaged through the heat transfer medium and called k_m, we may write:

$$\frac{dQ}{d\theta} = -k_m A \frac{\Delta t}{L}$$

where Δt is the difference (in degrees Fahrenheit) between the ambient air temperature, t_a, and the evaporating liquid temperature, t_l, and L is related to the thickness of the film through which this temperature change occurs.

The rate of heat supply is obviously equal to the product of the evaporation rate and the heat of vaporization of the liquids. It can be accurately assumed that the metallic pan used in the experiments offers no appreciable resistance to heat flow since calculations indicate that the resistance to heat flow offered by the pan itself is only about one four-thousandth that of the air film. In addition, the area A includes the top and bottom surface of the pan since the pan is suspended in the air. For our experiments, A was 40 sq. cm.

Assuming further that k_m is closely approximated by the thermal conductivity of air, k_a, we can write:

$$w = \left(\frac{k_a A}{B_a}\right)\left(\frac{-\Delta t}{\Delta H}\right)$$

where:

w = evaporation rate, g. per min.,
ΔH = heat of vaporization, cal. per g. at t_l,
$\Delta H_{25\,c.}$ = standard heat of vaporization cal. per g.,
k_a = thermal conductivity of air at temperature t_a, cal. per min. per sq. cm. deg. Fahr. per cm., and
B_a = "effective" film thickness of air under experimental, conditions.

If the air temperature and velocity are maintained constant, k_a and B_a are assumed constant as well as A, or:

$$w = \alpha \frac{(-\Delta t)}{\Delta H}$$

where:

$\alpha = k_a A / B_a$ = a constant.

Since ΔH for a pure hydrocarbon is a constant quantity for each temperature, define:

$$\Delta H = \beta \Delta H_{25\,c.}$$

where:

β = constant.

Substituting for ΔH in the rate equation and combining constants:

$$w = \frac{c(-\Delta t)}{\Delta H_{25\,c.}}$$

where:

$c = \alpha/\beta$.

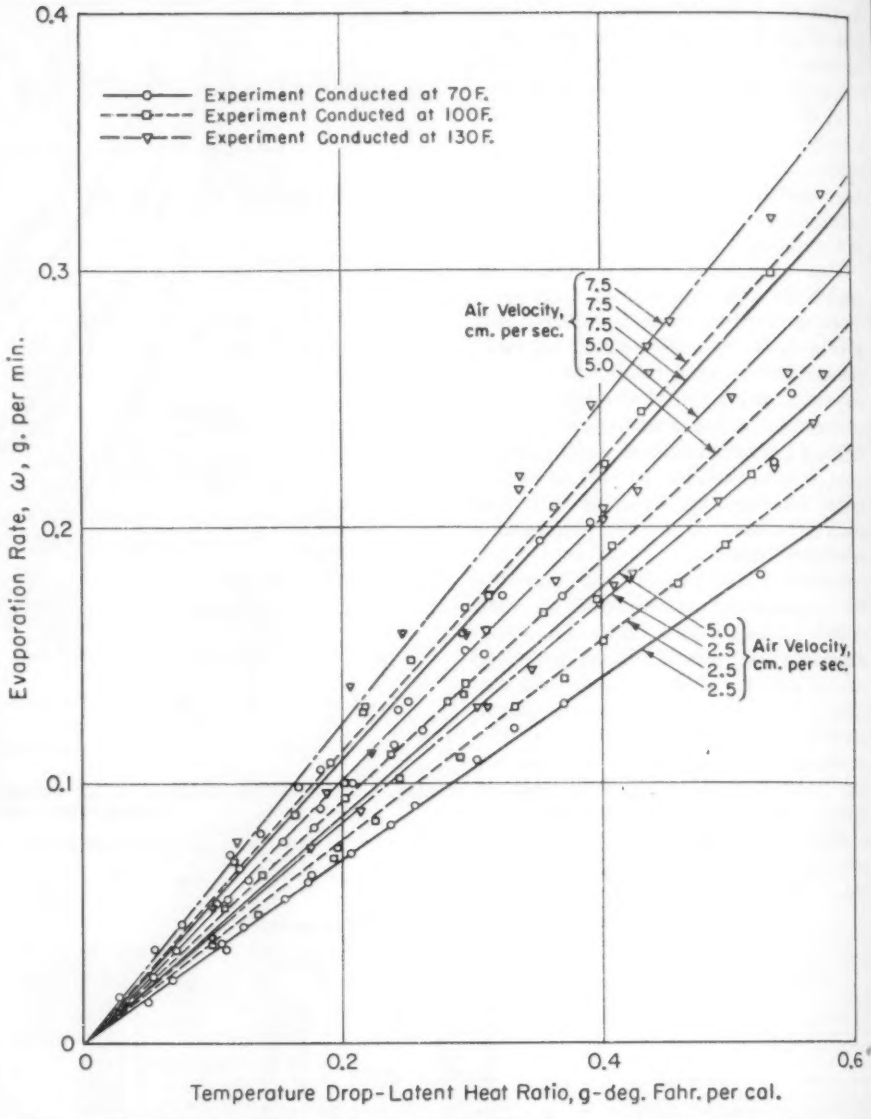


Fig. 3.—The Effect of Temperature and Air Velocity on the Evaporation Rate and Temperature Drop - Latent Heat Ratio Correlation.

The value of c would represent the slope of a plot of evaporation rate as a function of the ratio of the temperature drop to the standard heat of vaporization.

Such a plot is shown in Fig. 3 with data obtained for the various hydrocarbons. It will be noted that at constant temperature and velocity the data indicate straight lines; c is therefore concluded to be a function of velocity and, to a lesser degree, of temperature but is quite independent of the nature of the hydrocarbon.

From known values of the thermal conductivity of air,[4] the ratio of the heat of vaporization at t_l to the standard heat of vaporization, and from the smoothed experimental values of c, values were calculated for B_a. The results are given in Table II.

TABLE II.—CALCULATED VALUES OF EFFECTIVE FILM THICKNESS B_a FOR SEVERAL AIR VELOCITIES.

Air Velocity, cm. per sec.	$1/B_a$	B_a, mm.
2.5	4.39[a]	2.28
	4.35[b]	
	4.40[c]	
Avg.	4.38	
5.0	5.37[a]	1.88
	5.34[b]	
	5.26[c]	
Avg.	5.32	
7.5	6.46[a]	1.55
	6.40[b]	
	6.54[c]	
Avg.	6.47	

[a] t_a = 70 F. [b] t_a = 100 F. [c] t_a = 130 F.

Thus the apparent effective film thickness is of the order $1\frac{1}{2}$ to $2\frac{1}{4}$ mm., depending on the air velocity.

These values were fitted to the empirical equation[5]:

[4] John H. Perry (Editor), "Chemical Engineers Handbook," second edition, McGraw-Hill Book Co., Inc., New York, p. 959 (1941).

[5] The equation for the log B_a was obtained by averaging the slope after obtaining the intercept graphically.

$$\log B_a = -(0.5567 + 0.0339V)$$

where:

V = velocity of the air, cm. per sec.

Solving for B_a:

$$B_a = \frac{1}{10^{(0.5567 + 0.0339V)}}$$

This expression for B_a was then substituted in place of B_a in the equation for α, and c calculated from α and β. The differences between the experimental and calculated data are given in Table III.

TABLE III.—COMPARISON[a] OF EXPERIMENTAL AND CALCULATED VALUES OF CONSTANT (c) FOR SEVERAL VELOCITIES.

Air Velocity, cm. per sec.	Experimental Values of Constant	Calculated Values of Constant	Difference, per cent
2.5	0.36	0.359	−0.3
	0.386	0.389	0.8
	0.422	0.420	−0.5
5.0	0.440	0.436	−0.9
	0.474	0.472	−0.4
	0.504	0.510	1.2
7.5	0.530	0.531	0.2
	0.568	0.575	1.2
	0.628	0.620	−0.5

[a] Values were computed for data obtained at 70, 100, and 130 F., respectively, for each air velocity.

As can be seen, the numerical values are self-consistent. Using the equation for B_a it is therefore possible to calculate c. However, $-\Delta t$ still requires an experiment.

Correlation of Temperature Drop with Vapor Pressure:

The relationship of $-\Delta t$ and the vapor pressure of the evaporating hydrocarbon was investigated next. It was found that correlation of $-\Delta t$ with vapor pressure was possible through an empirical relationship:

$$\frac{-\Delta t}{p} = 0.0088\left(1 + \frac{V^2}{300}\right)(\beta\,\Delta H_{25\,\text{C.}})^{0.8}$$

where p = pressure, mm. mercury at t_l, and all other symbols have same significance and unit dimensions as before.

While it may not be immediately apparent, Δt and p are implicitly related, and this equation requires a trial-and-error solution. A graphical solution to a good approximation is possible and can be obtained as follows:

The vapor-pressure curve of the hydrocarbon is drawn on rectangular coordinates with the vapor pressure as ordinate and temperature as abscissa. At the point on the abscissa corresponding to the air temperature, a line is drawn with slope m, where:

$$m = 0.0088\left(1 + \frac{V^2}{300}\right)(\beta\,\Delta H_{25\,\text{C.}})^{0.8}$$

The intersection of this line with the vapor-pressure curve gives p and t_l. The temperature drop is read as the difference in temperature between the air and the liquid $(t_a - t_l)$.

Results on Temperature Drops and Evaporation Rates

Comparisons of the calculated and experimental temperature drops as well as evaporation rates are given in Table IV.

Discussion:

It will be noted that the largest deviations occur at 70 F., and particularly at the high air rate. The errors are largest for the higher boiling compounds. Experimental errors are also largest under these conditions since the evaporation rates are quite low, and the Jolly spring tended to start swinging at high air velocities.

The effect of humidity was investigated. No effect was found unless the humidity was high enough to cause condensation of moisture on the liquid. When this occurred, the evaporation rate became erratic. Condensation of moisture would increase heat transfer very significantly and cause higher observed evaporation rate since unit weight of condensed water would release sufficient heat for vaporizing several unit weights of hydrocarbon. On the other hand, the reduced vaporizing surface would act as a resistance.

No consideration has been given to the diffusivity of the vapors. We believe that our apparatus involving a flowing air stream justifies our neglect of this factor. Thermal conductivity of the hydrocarbon vapor has also been neglected; for the more volatile compounds, this may have been of some consequence, since one would expect appreciable concentrations of vapor in the "effective" film thickness through which the heat transfer occurred. For the less volatile compounds at the temperatures investigated, however, this was not serious.

Conclusion:

The work on pure hydrocarbons has shown that their evaporation rates can be found to correlate on a fairly good theoretical basis, aided by the introduction of some empirical factors.

Hydrocarbon Mixtures

It was originally expected that the extension of this work to hydrocarbon mixtures would prove to be complex. As a matter of fact, extension of the theory to binary or ternary mixtures turned out to be extremely complicated. However, when the more complex mixtures typified by petroleum solvents were investigated, it was found that a purely empirical correlation permitted a relatively easy prediction of the evaporation rate. This correlation is based on the A.S.T.M. distillation alone.[6]

While this correlation is purely empirical, it is based on a detailed study of the pure hydrocarbon data as well as attempts to extend the theory into two- and three-component systems. The mathematical manipulations involved in the theoretical development became extremely complex and could not be solved without the use of simplifying assumptions which would make the theory absurd.

Consequently it was assumed at the outset that correlations of sufficient precision would be obtained if the relatively small differences in the heats of vaporization of aromatics, naphthenes, and paraffins were neglected. It was also assumed that the temperature drop for the evaporating liquid would be determined by its boiling point, and would be independent of its chemical structure. When these simplifying assumptions were introduced into the theory it was found that the reciprocal of the evaporation rate was a logarithmic function of the boiling temperature.

Evaporation rates were measured on four petroleum "aromatic" and two petroleum "straight-run" solvents. The properties of these solvents are shown in Table V.

The evaporation rate data are given in Table VI. Reciprocal evaporation rates $(1/w)$ were plotted against the corresponding values of weight evaporated (in per cent) for each solvent studied. Average evaporation rates were obtained by the method of equal areas for the portions 0 to 35 per cent, 35 to 65 per cent, and 65 to 100 per cent evaporated on each curve. The reciprocals of these average evaporation rates were plotted on a logarithmic ordinate scale against the temperatures corresponding to the averaged A.S.T.M. distillation, per cent-evaporated points for 5, 10, 20, and 30 per cent; 40, 50, and 60 per cent; and 70, 80, 90, and 95 per cent (Fig. 4). These averages were taken rather than smoothed evaporation data corresponding to each A.S.T.M. point, mainly to reduce the significance of accidental errors.

The correlation is almost a linear relationship between log $1/w$ and boiling temperature.

Figure 4 was used to define the scale

[6] Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (D 86 – 46), 1949 Book of A.S.T.M. Standards, Part 5, p. 692.

TABLE IV.—COMPARISON OF EXPERIMENTAL AND CALCULATED TEMPERATURE DROPS AND EVAPORATION RATES OF HYDROCARBONS AT SEVERAL VELOCITIES AND TEMPERATURES.[a]

Compound	Temperature Drop ($-\Delta t$), deg. Fahr.						Difference in Temperature Drop, per cent			Evaporation Rate, w, g. per min.						Difference in Evaporation Rates, per cent		
	Experimental			Calculated						Experimental			Calculated					
Determinations at 70 F.																		
n-Pentane	45.9	46.8	48.0	46.8	48.1	50.2	2.0	2.8	4.6	0.181	0.226	0.252	0.192	0.240	0.305	6.1	6.2	21.0
2-Methyl pentane	27.5	28.3	29.2	27.6	28.5	30.1	0.4	0.7	3.1	0.121	0.156	0.194	0.120	0.150	0.193	−0.8	−3.8	−0.5
3-Methyl pentane	25.5	26.0	27.2	26.0	26.8	29.0	2.0	3.1	6.6	0.109	0.150	0.173	0.111	0.139	0.183	1.8	−7.3	5.8
n-Hexane	22.5	22.9	24.0	22.6	23.4	24.8	0.4	2.2	3.3	0.092	0.121	0.152	0.093	0.116	0.150	1.1	−4.1	−1.3
2,4-Dimethyl pentane	16.2	16.4	17.5	15.9	16.5	17.6	−1.9	0.6	0.6	0.073	0.100	0.129	0.073	0.092	0.119	−0.7	−8.0	−7.8
2,3-Dimethyl pentane	12.6	12.6	13.5	12.4	12.9	13.9	−1.6	2.3	2.2	0.055	0.077	0.099	0.055	0.069	0.090	−1.3	−10.4	−9.1
n-Heptane	9.5	9.6	10.4	9.2	9.6	10.4	−3.2	0.0	0.0	0.036	0.054	0.067	0.038	0.048	0.063	4.4	−11.1	−6.0
2,2,4-Trimethyl pentane (*iso*octane)	9.0	9.3	10.0	8.9	9.3	10.0	−1.1	0.0	0.0	0.045	0.064	0.081	0.043	0.055	0.072	−3.6	−13.4	−11.1
Benzene	17.9	18.3	18.7	17.8	18.5	19.7	−0.6	1.1	5.3	0.062	0.083	0.105	0.062	0.078	0.101	0.0	−6.0	−3.8
Toluene	6.7	7.0	7.3	6.7	7.0	7.6	0.0	0.0	4.1	0.024	0.036	0.046	0.024	0.031	0.041	−0.5	−14.8	−11.6
m-Xylene	...	...	2.6	...	...	2.5	...	...	−3.8	...	...	0.016	...	...	0.014	...	...	−15.2
Cyclopentane	36.0	36.0	38.0	37.7	38.8	40.6	4.7	7.8	6.8	0.131	0.173	0.202	0.139	0.174	0.222	6.1	0.6	9.9
Methyl cyclopentane	21.3	21.5	22.7	21.6	22.5	23.7	1.4	4.7	4.4	0.085	0.115	0.131	0.086	0.109	0.140	1.2	−5.2	6.9
Cyclohexane	16.5	17.0	17.8	17.4	18.1	19.3	5.5	6.5	8.4	0.066	0.091	0.108	0.066	0.084	0.109	0.0	−7.7	0.9
Methyl cyclohexane	9.0	9.5	9.6	9.3	9.7	10.5	3.3	2.1	9.4	0.038	0.056	0.073	0.039	0.049	0.065	2.1	−12.5	−11.0
Determinations at 100 F.																		
2-Methyl pentane	41.2	42.9	44.2	41.3	42.3	44.3	0.2	−1.4	0.2	0.193	0.229	0.298	0.194	0.241	0.308	0.5	5.2	3.4
3-Methyl pentane	38.6	...	...	39.2	40.2	42.2	1.6	...	...	0.178	0.220	...	0.181	0.226	0.289	1.7	2.7	...
n-Hexane	35.1	35.9	37.9	35.2	36.3	38.1	0.3	1.1	0.5	0.155	0.193	0.245	0.156	0.196	0.250	0.6	1.6	2.0
2,4-Dimethyl pentane	26.4	27.8	28.8	26.2	27.1	28.7	−0.8	−2.5	−0.3	0.130	0.167	0.208	0.130	0.163	0.210	0.0	−2.4	1.0
2,3-Dimethyl pentane	21.6	23.0	24.1	21.3	22.2	23.5	−1.4	−3.5	−2.5	0.103	0.132	0.159	0.102	0.128	0.166	−1.0	−3.0	4.4
n-Heptane	17.2	17.9	19.1	16.9	17.5	18.8	−1.7	−2.2	−1.6	0.076	0.100	0.130	0.076	0.095	0.124	0.0	−5.0	−4.6
2,2,4-Trimethyl pentane (*iso*octane)	16.7	17.5	18.6	16.1	16.8	18.0	−3.6	−4.0	−3.2	0.086	0.112	0.148	0.085	0.108	0.141	−1.2	−3.6	−4.7
Benzene	28.5	30.4	30.7	29.1	30.1	31.7	2.1	−1.0	3.3	0.107	0.135	0.169	0.109	0.137	0.176	1.8	1.5	4.1
Toluene	13.4	13.6	16.0	12.9	13.5	14.5	−3.7	−0.7	−9.4	0.048	0.066	0.088	0.051	0.065	0.085	5.2	−1.5	−3.4
Methyl cyclopentane	33.3	35.5	36.4	33.7	34.8	36.6	1.2	−2.0	0.8	0.141	0.172	0.224	0.146	0.183	0.235	3.5	6.4	4.9
Cyclohexane	27.3	27.9	29.6	28.3	29.2	30.8	3.7	4.7	4.1	0.110	0.139	0.173	0.117	0.147	0.189	6.4	5.8	9.2
Methyl cyclohexane	16.6	17.5	18.8	17.0	17.5	18.7	2.4	0.0	−0.5	0.072	0.095	0.128	0.077	0.096	0.125	6.9	0.9	−2.3
Determinations at 130 F.																		
n-Hexane	49.7	50.2	52.8	49.7	51.2	53.4	0.0	2.0	1.1	0.240	0.260	0.360	0.239	0.298	0.378	−0.4	14.6	5.0
2,4-Dimethyl pentane	38.4	39.3	41.9	38.8	39.9	42.0	1.0	1.5	0.2	0.210	0.250	0.320	0.208	0.260	0.332	−1.0	4.0	3.7
2,3-Dimethyl pentane	32.4	32.8	35.7	32.8	33.8	35.8	1.2	3.0	0.3	0.171	0.203	0.270	0.168	0.211	0.272	−1.8	3.9	0.7
n-Heptane	27.2	27.4	29.5	27.3	28.1	29.9	0.4	2.6	1.3	0.130	0.158	0.216	0.131	0.164	0.213	0.8	3.8	−1.4
2,2,4-Trimethyl pentane (*iso*octane)	25.5	26.8	28.9	25.8	26.8	28.4	1.2	0.0	−1.7	0.145	0.179	0.247	0.147	0.186	0.240	1.4	3.9	−2.8
Benzene	42.5	...	45.5	42.9	...	46.2	0.9	...	1.5	0.177	0.207	0.260	0.174	0.217	0.277	−1.7	4.8	6.5
Toluene	21.2	22.0	24.2	21.9	22.7	24.2	3.3	3.2	0.0	0.090	0.112	0.159	0.093	0.117	0.153	3.3	4.5	−3.8
m-Xylene	9.3	9.5	11.2	9.7	10.2	11.1	4.3	7.3	−0.9	0.040	0.053	0.077	0.042	0.054	0.072	5.6	2.0	−7.1
Methyl cyclopentane	48.0	49.0	51.4	48.1	49.5	51.7	0.2	1.0	0.6	0.223	0.257	0.330	0.226	0.281	0.358	1.3	9.3	8.5
Cyclohexane	40.0	40.3	42.6	41.5	42.7	44.8	3.7	6.0	5.2	0.181	0.214	0.280	0.186	0.232	0.296	2.8	8.4	5.7
Methyl cyclohexane	26.2	26.8	29.2	27.0	27.6	29.7	3.1	3.0	1.7	0.130	0.160	0.220	0.131	0.163	0.214	0.8	1.8	−2.7

[a] The three values shown for each compound, under each quantity measured, were obtained with the experimental air velocities being (from *left* to *right*) 2.5, 5.0, and 7.5 cm. per sec., respectively.

TABLE V.—PHYSICAL PROPERTIES AND A.S.T.M. DISTILLATION RANGES FOR SOME HYDROCARBON MIXTURES.

Mixture	Gravity, deg. A.P.I., 60 F.	Aniline Point	Analysis, Volume per cent			A.S.T.M. Distillation Temperature, deg. Fahr.												
			Aromatics	Napthenes	Paraffins	Initial Boiling Point	When Per Cent Distilled is										Dry	End Point
							5	10	20	30	40	50	60	70	80	90	95	
Aromatic No. 1	41.9	15	57	29	14	220	227	228	230	232	235	237	242	246	252	262	273	285	295
Aromatic No. 2	38.1	1	67	23	10	242	252	256	260	264	270	274	280	288	295	306	315	...	340
Aromatic No. 3	35.0	76[a]	74	21	5	284	294	295	297	300	304	308	312	318	326	340	350	...	368
Aromatic No. 4	33.1	85[a]	69	27	4	306	318	321	329	336	342	248	355	362	370	383	394	...	408
Straight run No. 1	55.1	107	12	56	32	192	200	204	207	210	215	219	224	230	237	249	257	267	287
Straight run No. 2	44.4	116	20	59	21	324	330	332	334	336	338	340	342	344	348	355	366	...	383

[a] Mixed aniline point.

TABLE VI.—EVAPORATION RATES OF SOME HYDROCARBON MIXTURES

Air Velocity, 5 cm. per sec.; Air Temperature, 100 F.

Time Elapsed, min.	Weight Evaporated During Interval, g.	Total Weight Evaporated, per cent	Evaporation Rate for Interval, w, g. per min.	$1/w$, min. per g.
Aromatic No. 1 (Sample wt. = 1.202 g.)				
1	0.0746	6.2	6.2	0.161
2	0.0746	12.4	6.2	0.161
3	0.0672	18.0	5.6	0.179
4	0.0653	23.4	5.4	0.184
5	0.0653	28.9	5.4	0.184
6	0.0653	34.3	5.4	0.184
7	0.0634	40.0	5.3	0.189
8	0.0597	44.5	5.0	0.202
9	0.0597	49.5	5.0	0.202
10	0.0578	54.3	4.8	0.208
11	0.0504	58.5	4.2	0.239
12	0.0504	62.7	4.2	0.239
13	0.0541	67.2	4.5	0.222
14	0.0448	70.9	3.7	0.269
15	0.0448	74.6	3.7	0.269
16	0.0429	78.2	3.5	0.280
17	0.0410	81.6	3.4	0.293
18	0.0373	84.7	3.1	0.323
19	0.0373	87.8	3.1	0.323
20	0.0354	90.7	2.9	0.340
21	0.0336	93.5	2.8	0.358
22	0.0280	95.8	2.3	0.429
23	0.0261	98.0	2.2	0.461
24	0.0205	99.7	1.7	0.588
25	0.0037	100.0	0.3	3.330
Aromatic No. 2 (Sample wt. = 1.216 g.)				
1	0.0448	3.7	3.7	0.27
2	0.0448	7.3	3.7	0.27
3	0.0410	10.7	3.4	0.30
4	0.0373	13.8	3.1	0.33
5	0.0373	16.8	3.1	0.33
6	0.0354	19.7	2.9	0.34
8	0.0728	25.7	3.0	0.33
10	0.0690	31.4	2.8	0.35
12	0.0616	36.4	2.5	0.40
14	0.0634	41.6	2.6	0.39
16	0.0560	46.2	2.3	0.44
18	0.0560	50.8	2.3	0.44
20	0.0504	54.9	2.1	0.48
22	0.0466	58.7	1.9	0.52
24	0.0429	62.3	1.8	0.57
26	0.0485	66.2	2.0	0.50
28	0.0410	69.6	1.7	0.60
30	0.0410	73.0	1.7	0.60
32	0.0410	76.3	1.7	0.60
36	0.0672	81.8	1.4	0.72
40	0.0653	87.2	1.4	0.69
44	0.0504	91.3	1.0	0.97
50	0.0653	96.7	0.9	1.12
55	0.0410	100.0	0.7	1.49
Aromatic No. 3 (Sample wt. = 1.257 g.)				
1	0.0224	1.8	1.8	0.56
2	0.0205	3.4	1.6	0.61
3	0.0205	5.0	1.6	0.61
4	0.0224	6.8	1.8	0.56
8	0.0765	12.9	1.5	0.66
12	0.0802	19.3	1.6	0.63
16	0.0765	25.4	1.5	0.66
20	0.0709	31.0	1.4	0.71
24	0.0653	36.2	1.3	0.77
29	0.0802	42.6	1.3	0.78
32	0.0504	46.6	1.3	0.75
36	0.0578	51.2	1.2	0.87
40	0.0560	55.6	1.1	0.90
44	0.0541	59.9	1.1	0.93
48	0.0485	63.8	0.97	1.03
52	0.0466	67.5	0.93	1.08
56	0.0429	70.9	0.85	1.17
60	0.0410	74.2	0.82	1.23
64	0.0373	77.1	0.74	1.35
68	0.0373	80.1	0.74	1.35
72	0.0299	82.5	0.60	1.68
76	0.0336	85.2	0.67	1.50
82	0.0448	88.7	0.59	1.69
88	0.0354	91.5	0.47	2.13
94	0.0336	94.2	0.45	2.25
100	0.0299	96.6	0.40	2.52
106	0.0243	98.5	0.32	3.11
112	0.0187	100.0	0.25	4.03

Time Elapsed, min.	Weight Evaporated During Interval, g.	Total Weight Evaporated, per cent	Evaporation Rate for Interval, w, g. per min.	$1/w$, min. per g.
Aromatic No. 4 (Sample wt. = 1.231 g.)				
2	0.0168	1.4	0.68	1.47
4	0.0187	2.9	0.76	1.32
8	0.0354	5.8	0.72	1.39
15	0.0802	12.3	0.93	1.08
22	0.0634	17.4	0.74	1.36
30	0.0634	22.6	0.64	1.55
40	0.0728	28.5	0.59	1.69
46	0.0429	32.0	0.58	1.72
50	0.0261	34.1	0.50	1.99
53	0.0187	35.6	0.51	1.97
60	0.0429	39.1	0.50	2.01
75	0.0858	46.1	0.47	2.15
90	0.0784	52.4	0.43	2.35
105	0.0690	58.0	0.37	2.68
120	0.0597	62.9	0.32	3.10
128	0.0336	65.6	0.34	2.93
150	0.0784	72.0	0.30	3.46
180	0.0933	79.5	0.25	3.97
210	0.0746	85.6	0.20	4.95
240	0.0634	90.8	0.17	5.81
270	0.0522	95.0	0.14	7.09
285	0.0205	96.7	0.11	9.00
300	0.0205	98.3	0.11	9.00
315	0.0149	99.6	0.08	12.34
330	0.0056	100.0	0.03	33.00
Straight-Run No. 1 (Sample wt. = 1.082 g.).				
1	0.1026	9.5	9.5	0.106
2	0.1026	19.0	9.5	0.106
3	0.0970	27.9	8.9	0.112
4	0.0877	36.0	8.1	0.123
5	0.0896	44.3	8.3	0.121
6	0.0746	51.2	6.9	0.145
7	0.0746	58.1	6.9	0.145
8	0.0746	65.0	6.9	0.145
9	0.0672	71.2	6.2	0.161
10	0.0560	76.4	5.2	0.193
11	0.0522	81.2	4.8	0.208
12	0.0541	86.2	5.0	0.200
13	0.0448	90.3	4.1	0.242
14	0.0392	94.0	3.6	0.276
15	0.0392	97.6	3.6	0.276
16	0.0243	99.8	2.2	0.444
17	0.0019	100.0	0.2	5.550
Straight-Run No. 2 (Sample wt. = 1.205 g.)				
1	0.0243	2.0	2.00	0.50
2	0.0112	2.9	0.93	1.08
3	0.0093	3.7	0.77	1.30
5	0.0187	5.3	0.78	1.29
10	0.0317	7.9	0.53	1.90
20	0.0914	15.5	0.76	1.32
30	0.0933	23.2	0.77	1.29
40	0.0821	30.0	0.68	1.47
45	0.0373	33.1	0.62	1.62
53	0.0672	38.7	0.70	1.44
60	0.0560	43.3	0.66	1.51
82	0.1586	56.5	0.60	1.67
95	0.0821	63.3	0.52	1.91
105	0.0709	68.2	0.60	1.70
120	0.0858	76.3	0.48	2.11
130	0.0560	81.0	0.47	2.15
140	0.0504	85.1	0.42	2.39
150	0.0504	89.3	0.42	2.39
160	0.0410	92.7	0.34	2.94
167	0.0261	94.9	0.31	3.23
180	0.0410	98.3	0.26	3.82
190	0.0187	99.8	0.15	6.45
205	0.0019	100.0	...	...

of $1/w$ in a plot of $1/w$ *versus* temperature (Fig. 5).

Summary and Conclusion

For pure hydrocarbons the evaporation rate is a function of the vapor pressure and heat of vaporization at the liquid temperature, the difference in temperature between evaporating liquid and ambient air, the velocity of air past the evaporating surface, the thermal conductivity of air at ambient air temperature and the area of the evaporating surface.

Figure 5 summarizes all the data on evaporation rates of hydrocarbon mixtures obtained in this study.

The curves are the A.S.T.M. distillation curves and refer to the abscissa and the left-hand ordinate. The open circles are the evaporation rate data on the aromatic solvents plotted as the reciprocal of the evaporation rate, $1/w$; the solid circles are the reciprocal evaporation rates on the straight-run solvents.

As can be seen, the correlation be-

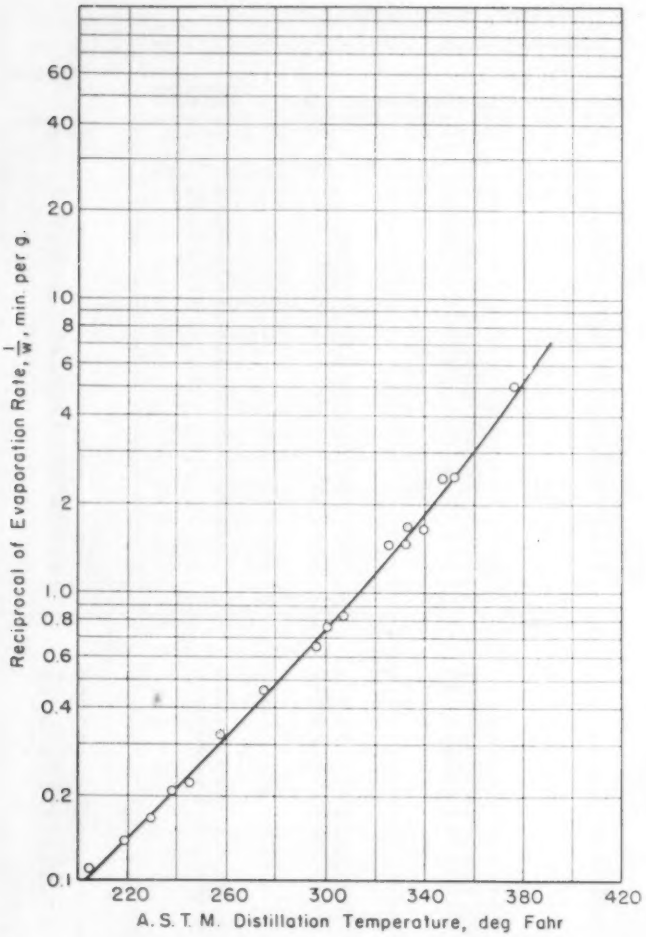


Fig. 4.—Correlation of Evaporation Rate and A.S.T.M. Distillation Temperature.

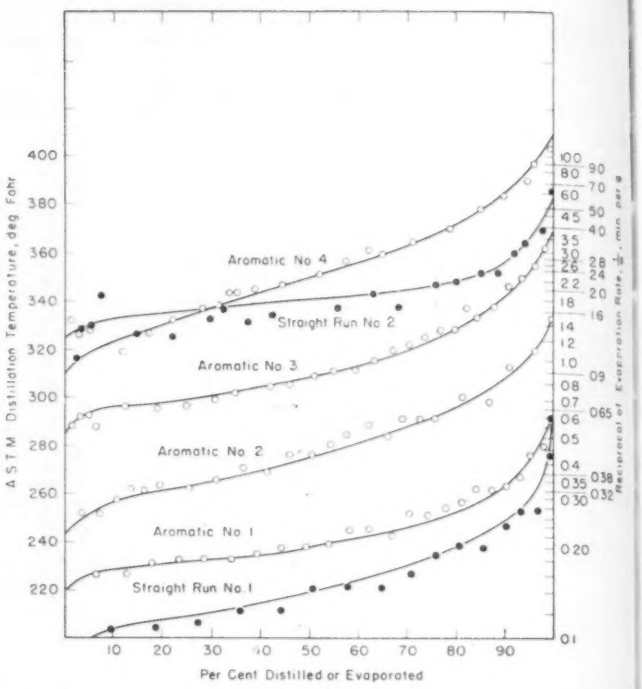


Fig. 5.—Correlation of A.S.T.M. Distillation Rate and Evaporation Rate.

Air Rate, 5 cm. per sec.; Air Temperature, 100 F. The curves are the A.S.T.M. distillation curves and refer to the abscissa and left hand ordinate. The points plotted on these curves are the reciprocal evaporation rates; open circles are for aromatic solvents, the solid circles are for straight run solvents.

tween reciprocal evaporation rates and A.S.T.M. diltillation values is good. There is a tendency for the $1/w$ points for the straight-run solvents to fall slightly below the A.S.T.M. curve, indicating that the volatility of these materials is somewhat higher than the correlation would indicate. This might be expected, since the nonaromatic hydrocarbons, as a class, have lower heats of vaporization than other hydrocarbons.

Nevertheless, to a very good approximation, it is apparent that evaporation rates of hydrocarbon mixtures can be compared almost exclusively by their A.S.T.M. distillations. There seems to be no need for any other type of specification control on the volatility of solvent materials, with the possible exception of controls on nonvolatile residues arising from accidental contamination.

Composition of the solvent mixture, particularly its aromatic content, influences evaporation rate slightly, the aromatic hydrocarbons, as a class, showing lower evaporation rates than other groups at the same boiling point.

Acknowledgement:

Many details of the apparatus used in this investigation were developed by C. E. Johnson. He also obtained the experimental data and made the correlation of the evaporation rates of the pure compounds. This work is gratefully acknowledged.

DISCUSSION

MR. C. M. SHAW[1] (*presented in written form*).—Mr. Galstaun has presented a description of a fine piece of research on evaporation rates of hydrocarbons under definite controlled conditions. The apparatus used for this work has been calibrated with sufficient precision to give results which can be used to correlate with thermodynamic properties. Mr. Galstaun has developed a mathematical formula which shows a relationship between evaporation rates and the thermodynamic properties. Although the derivation of the equation is partially empirical, the results obtained show that the equation is for all practical purposes sufficiently accurate for the calculation of the evaporation rates of pure hydrocarbons.

The evaporation rates were measured under conditions where the velocity of the air moving over the evaporating sample is high enough so that diffusion rates of the solvent through the air layer above the sample need not be considered. If the air velocity were reduced so as to approach more nearly practical drying conditions, it would be necessary to consider diffusion rates as well as air velocity. Lewis and Squires[2] in 1937 showed the importance of considering diffusion evaporation from lacquer solvents. The introduction of diffusion constants into the equation of evaporation rates, however, is necessary only at low air speeds.

[1] California Research Corp., Richmond, Calif.
[2] W. K. Lewis and L. Squires, "Evaporation of Mixed Lacquer Solvents," *Industrial and Engineering Chemistry*, Vol. 29, January, 1937, pp. 109–114.

The author's data on pure hydrocarbons show that the evaporation rate of paraffinic hydrocarbons is about 20 per cent faster than for aromatic compounds of the same boiling point. However, his data on petroleum thinner fractions show that the evaporation rate is independent of the nature of the hydrocarbon. A possible explanation of this phenomenon is the formation of azeotropic mixtures of paraffin and aromatic hydrocarbons. In fact, this may also be the reason why efforts to extrapolate data obtained on pure hydrocarbons to mixtures of hydrocarbons have failed.

Mr. Galstaun's data show that the evaporation rate of petroleum solvents under the conditions of his measurements correlates with the ASTM D 86 distillation. If the air flow above the evaporating sample were reduced to a rate such that diffusion of the solvent through the air layer was an important factor in the evaporation rate, this correlation with D 86 distillation might not be so satisfactory. The diffusion rate of the higher molecular weight hydrocarbons will show differences during evaporation which in all probability will not correlate with D 86 distillation.

One factor which must be considered when utilizing the data correlating D 86 distillation of petroleum solvents and evaporation rates is that straight-line blending of two solvents whose D 86 distillation are known will not necessarily give the evaporation rate of the intermediate blend. The concentration of the components being blended must be given consideration, and the D 86 distillation of the blend should be obtained before attempting to utilize the vaporation rate data. This is particularly important when blending aromatic and paraffinic stocks. The possible formation of azeotropes which would change both the distillation range and the evaporation range should not be overlooked.

It should be pointed out that evaporation rate measurements obtained by Mr. Galstaun's equipment and on nearly all evaporation rate equipment in common use today do not give information which is directly applicable to the evaporating conditions encountered in the paint, varnish, and lacquer industry. Evaporation rates from protective coating films will depend upon such factors as shrinkage pressure, polymerization rate, and diffusion rate through viscous films. Under these practical conditions, solvents which appear to have a low rate of evaporation as measured by D 86 distillation will sometimes escape from a film faster than would be expected because of their higher rates of diffusion and lack of polarity. This is particularly so in certain alkyd resin solutions where the higher polarity of aromatic molecules tends to keep them in the film longer than a paraffinic molecule of a higher boiling range.

We feel that information such as that obtained by Galstaun and his group is a very definite contribution to our fundamental knowledge of petroleum hydrocarbons. We are certain that additional work along the lines indicated will throw further light on the more practical aspects of the evaporation rates of hydrocarbons which will permit use of these data by the paint, varnish, and lacquer industry.

MR. M. B. CHITTICK[3] (*presented in written form*).—Mark Twain's classic statement in reference to the weather can be paraphrased, for the benefit of those industries and individuals who have to do with petroleum thinners, to the effect that everybody has talked about evaporation rates but no one has done anything about it. This is figuratively true. There is every indication, however, that the tide has turned and this year two real contributions have been made. I refer to the paper "Hydrocarbon Solvents: Types and Uses" by Boggs (presented in January, 1949, in Detroit as one of a series of lectures on the "Technology of Surface Coatings" sponsored jointly by Wayne University, the Detroit Paint, Varnish and Lacquer Assn., and the Detroit Production Club), a lecture sponsored by Hercules Powder Co., and the paper just presented by Mr. Galstaun.

One has to make only a cursory survey of the several empirical methods of tests for the so-called determination of evaporation rates of these solvents and thinners to be thoroughly deflated in any ego as to our over-all scientific progress.

Mr. Galstaun is to be congratulated on this paper. His concept of the problem and practical approach constitute a substantial contribution.

I have selected the published evaporation rates on six solvents that approximate the hydrocarbon analysis and ASTM Distillation ranges reported in Mr. Galstaun's letters. These are as follows:

	Galstaun's Report	Published
Aromatic No. 1	25 min.	6¾ min.
Aromatic No. 2	55 min.	14 min.
Aromatic No. 3	112 min.	55 min.
Aromatic No. 4	330 min.	140 min.
Straight-Run No. 1	17 min.	5¾ min.
Straight-Run No. 2	205 min.	160 min.

We know from actual application results that the published results are inaccurate and therefore useless in so far as forecasting results. By the same token the evaporation rates in the paper we have just heard are more in line with actual application.

It is believed that any discrepancies can be explained by differences in air temperature, humidity, and the many other variables.

It would be interesting to know how closely results would compare on the procedure used by Galstaun and the procedure described by Boggs.

Harvey and Mills have reported on a correlation of Kaurl butanol solvency with gravity and aniline point.[4] The question arises as to whether in Mr. Galstaun's opinion some similar correlation of evaporating rates might not be in the realm of possibilities.

Industry should give Mr. Galstaun and his associates a vote of thanks for this contribution.

MESSRS. R. W. TESS, J. N. WILSON, AND C. H. KLUTE[5] (*presented in written form.*)—The author has pointed out, quite rightly, that the rate of evaporation is dependent upon the steady-state flow of energy from the surroundings to the liquid. As the sample evaporates, it cools, its vapor pressure decreases, and the rate of evaporation decreases. At the same time, as it cools, the flow of heat into it from the surroundings increases. A balance is struck when the flow of heat into the sample from the surroundings becomes equal to the flow of heat out of the sample by evaporation.

In the experiments carried out, the liquid films were relatively thick (apparently of the order of 30 mils) and it may be true that the bulk of the liquid evaporates under these steady-state conditions. However, when considering paint films of the order of 2 mils, the bulk of the liquid may evaporate before steady-state conditions are attained; the steady-state analysis used by the author may not account for this more complicated situation. A better understanding of the operation of the author's apparatus would be afforded by the presentation of data showing the rate of evaporation of a pure liquid as a function of time from the beginning of the run until the sample has completely evaporated.

The author has used the heat-balance principle in calculating, from measured rates of evaporation and liquid temperatures, the values of the heat transfer coefficient (in the form of c) as a function of air velocity in a particular physical system. The heat transfer coefficient has been described in terms of an "effective film thickness" (designated B_e), and

[3] American Mineral Spirits Co., New York, N. Y.

[4] W. T. Harvey and I. W. Mills, "Petroleum Solvents," *Analytical Chemistry*, Vol. 20, March, 1948, pp. 207–209.

[5] Shell Development Co., Emeryville, Calif.

an empirical equation has been proposed for the effective film thickness as a function of air velocity. The author's Table II shows that the "effective film thickness" is independent of ambient temperature at temperatures of 70 to 130 F., and Table III shows that the empirical equation for B_a fits the data well under the conditions used.

Calculation of B_a from the equation

$$B_a = \frac{k_a A}{c\beta} \text{ where } \beta = \frac{\Delta H}{\Delta H_{25\,c.}}$$

necessitates the assignment of a numerical value for β. It would be helpful to know more precisely how β was obtained and what its value was found to be, since it is not immediately apparent that such a function would be independent of the hydrocarbon and the Δt involved. It may be worth while, therefore, to investigate this point further.

An approximation of the value of β may be obtained by use of the Antoine equation as given in the API tables.

$$\log_{10} P = A - \frac{B}{C + t}$$

where P = pressure in mm. of mercury, t = deg. Cent., and A, B, and C are constants characteristic of the hydrocarbon. Substituting the Antoine equation into the Clapeyron equation, we obtain

$$\Delta H = \frac{RT^2 d \log_e p}{dT} = \frac{2.3\ BRT^2}{(C' + T)^2}$$

where $C' = C - 273.1$, ΔH = heat of vaporization at t_b, and T = absolute temperature. Then bearing in mind that $T = 298 + \Delta t$ we can obtain an equation for the value of β.

$$\beta = \frac{\Delta H}{\Delta H_{298}} =$$

$$\left(\frac{298 + \Delta t}{298}\right)^2 \left(\frac{C' + 298}{C' + 298 + \Delta t}\right)^2 =$$

$$\left(\frac{298 + \Delta t}{298}\right)^2 \left(\frac{C + 25}{C + 25 + \Delta t}\right)^2$$

Since Δt has a maximum value of about 25 C. and C varies from about 215 (paraxylene) to 232 (pentane) for the hydrocarbons considered, it can be seen that β is relatively insensitive to temperature and the nature of the hydrocarbon when the hydrocarbon has a boiling point within the range represented in the experiments.

The heat transfer coefficients are really averages for the metal surface and liquid surface and are composite values of radiation and conduction components. It has not been shown that the coefficients are independent of the size and shape of the pans or of the depth to which the pans are filled. The latter variable may conceivably be significant since the lip of the pan will introduce some air convection which will modify the heat transfer, and as the liquid layer becomes thinner, mixing of the liquid by convection will be inhibited and an appreciable temperature gradient may arise between the bottom of the pan and the liquid surface. Application of the same treatment to viscous liquids such as paint or varnish will be complicated by the fact that the temperature of the liquid phase will not be kept so uniform by convection. Consequently the heat transfer from the bottom will be different from that from the top of the liquid.

The author has presented an empirical relationship between the vapor pressure of the liquid and its drop in temperature relative to the ambient air. The equation involves air velocity and heat of vaporization. Solution of the equation led to excellent correlations between the calculated and experimental values of Δt, that, is, the difference in temperature between the ambient air and liquid surface. Knowledge of Δt is desirable because use of its value along with the heat transfer coefficient and the latent heat of evaporation would permit calculation of the evaporation rate.

An alternative relationship of vapor pressure and ΔT in terms of the heat transfer coefficient can be derived by equating the evaporation rate as derived from kinetic theory to the evaporation rate as determined by the flow of heat into the liquid.

$$kA_s p_v \sqrt{\frac{M}{2\pi RT_s}} = \frac{hA\Delta T}{\Delta H_{T_s}} \text{ (g. per sec.)}$$

where

A_s = surface area of liquid,
T_s = temperature of liquid surface,
M = molecular weight of liquid,
k = accommodation coefficient,
p_v = vapor pressure of liquid at T_s,
h = over-all heat transfer coefficient relating to the total heat transfer area A,
ΔH_{T_s} = heat of vaporization per gram at T_s, and
ΔT = difference in temperature between liquid and surroundings.

$$\frac{\Delta T}{p_v} = \frac{k}{h} \Delta H_{T_s} \frac{A_s}{A} \sqrt{\frac{M}{2\pi RT_s}}$$

And this equation could be solved in a manner similar to that of the author's, by utilizing a plot of p_v *versus* T and a line of slope $-\left[\frac{k}{h} \Delta H_{T_s} \frac{A_s}{A} \sqrt{\frac{M}{2\pi RT_s}}\right]^{-1}$, if it were not for the difficulty of choosing a suitable value for the accommodation coefficient, k (see G. Wyllie, *Proceedings* Royal Soc. London, A197,383 (1949)). The value of k for benzene is about 0.9; the excellence of the author's empirical correlation suggests that the value of k for hydrocarbons varies with molecular weight in a regular way. The above equation might be used to compute effective values of k for the pure hydrocarbons studied by the author. If an independent estimate of k could be obtained, it would be interesting to see how this theoretical equation compares with the empirical one. It should be emphasized that neither this nor the author's method will apply to paint layers directly since the pressure-temperature curve will be modified by the presence of oil and resin.

Regarding the effect of humidity on evaporation rate, it has been reported by others that increased humidity caused lower observed evaporation rate under certain particular conditions. In a paper presented at the Spring 1949 meeting of the American Chemical Society, Curtis, Scheibli, and Bradley presented data showing that a mixed hydrocarbon as well as methyl ethyl ketone, ethyl alcohol, ethyl acetate, methyl isobutyl ketone, and isopropyl alcohol each evaporated from filter paper more slowly at higher humidity (50 *versus* 1.5 per cent relative humidity). Also Rudd and Tysall, in a recent paper presented before the Rothesay Conference of the Oil and Colour Chemists Association in May, 1949, have shown that acetone (but not *n*-butyl acetate) evaporated from a metal surface more slowly at a higher humidity (70 *versus* 30 per cent relative humidity).

In the last part of the paper the author has presented figures which indicate a good correlation of ASTM distillation data with evaporation rates. Since the heat transfer coefficients enter implicitly, the correlation is valid only for steady-state evaporation under the particular conditions used for the measurement of evaporation rates and is applicable only to the limited range of hydrocarbon mixtures tested. The curves show that the straight-run thinners evaporated somewhat faster than the ASTM distillation data would predict. In view of the fact that the particular straight-run distillates tested consisted predominantly of naphthenes and aromatics which have been shown by the author and others to evaporate more slowly than the paraffins of equal boiling point, it would be expected that predominantly paraffinic thinners such as are commonly marketed in the East would deviate considerably more from the behavior predicted by the ASTM distillation data than the products actually tested. On the other hand, it remains to be shown that straight aromatic mixtures correlate adequately, since the maximum aromatic content of the products investigated comprised 75 per cent. It would be expected that the correlation could not be applied to non-

hydrocarbons for which the heat of evaporation per gram is different from that of hydrocarbons, or even to hydrocarbons lying outside the volatility range investigated. The correlations will be of limited use unless it can be shown that they can be applied to solutions of resins and oils similar to those normally encountered in the application of surface coatings.

MR. L. S. GALSTAUN (*author's closure*).—Mr. Shaw has properly raised a question as to the applicability of the correlations presented in the event that the air velocity is reduced to the point where diffusion rate will begin to control evaporation. He also points out correctly, that in such a case, the diffusion rate will vary with molecular weight for substances boiling close to each other.

It would seem that except for essentially motionless air, free from convection and other similar mass movement, conditions would not be set up for control of evaporation by diffusion rate. In a practical way, the velocities used in this research are not very high and may be encountered outdoors any time there is a barely perceptible breeze.

Mr. Chittick has raised the interesting question of a correlation of evaporation rates with API gravities and aniline points, in the manner that Harvey and Mills used for the Kauri Butanol Value. By bringing in the API gravity or the aniline point, undoubtedly an improvement could be made in the correlation of evaporation rate with the D 86 distillation. The correction needed on the present correlation based on the D 86 distillation is not large and we simply felt that it was hardly worth the effort, especially since evaporation rates are so sensitive to ambient conditions, which generally cannot be regulated with the precision we were able to obtain in our apparatus.

Messrs. Tess, Wilson, and Klute raise a question on the term β. This value was determined from published tables of API *Project 44*, by interpolating to obtain ΔH_1. Their derivation of β based on the Clapeyron and Antoine equations is interesting. In our case, we were led to the use of β by a similar derivation based on the use of the Kirchhoff equation. We came to the same conclusion.

As Messrs. Tess, Wilson, and Klute also point out, the heat transfer coefficients are averages for the liquid and metal surfaces. In our experiments, a thermal steady state was established within 2 min. after the start of evaporation. Even with films of 20 to 30 mils thickness, it is hard to believe that thermal gradients of any appreciable magnitude could be present in the liquid regardless of the possibility of convection heat flow. Transfer of heat by conduction through such thin films should be ample to reduce any diffrence in temperature between the liquid and metal surfaces to a negligible value compared to Δt.

With regard to the nature of petroleum thinners marketed in the East, our experience has been that these differ from western thinners to a relatively minor degree in aromatic content; the big difference between eastern and western thinners is in the preponderance of naphthenes in western thinners, and the preponderance of paraffins in the eastern product. Accordingly we believe that our correlation stands an excellent chance of being valid for eastern thinners as well.

It is of course true, as has been pointed out by all the discussers, that the data cannot be applied directly to paint or varnish films. Such was not the intent of this study.

Automatic Control of Thermal Conductivity Apparatus[1]

By E. M. Herrmann,[2] R. B. Plate,[3] and W. P. Sinclair[3]

SYNOPSIS

This paper describes the pertinent features of the apparatus used for determining the thermal conductivity of insulating materials at the U. S. Naval Engineering Experiment Station, Annapolis, Md. The description of the apparatus is sufficiently complete for its construction by other testing facilities. Examples of data automatically recorded, charts showing the accuracy of the control instruments, and a sample curve of the calculated thermal conductivities are illustrated. Use of the equipment saves time and money, insures reproducibility and accuracy of results, and requires very little surveillance and maintenance.

THE Materials Section of the Chemical Engineering Laboratory of the U. S. Naval Engineering Experiment Station has the responsibility of approval testing of all the thermal insulating materials (excluding ceramics) used aboard Naval vessels. Recently this Section was required to move its thermal conductivity apparatus to another location. Involved in the transfer of the equipment was the necessity of hiring additional watch-standing personnel. As a means of preventing possible increase in maintenance costs and to increase the efficiency of the apparatus, funds were made available to investigate the feasi-

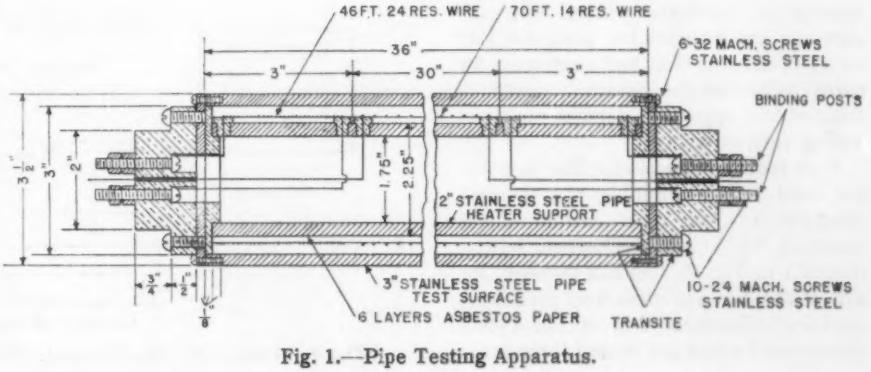


Fig. 1.—Pipe Testing Apparatus.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Presented at the Fifty-third Annual Meeting of the Society, June 26–30, 1950.

[2] Wave Mechanics Laboratory, U. S. Naval Engineering Experiment Station, Annapolis, Md.

[3] Chemical Engineering Laboratory, U. S. Naval Engineering Experiment Station, Annapolis, Md.

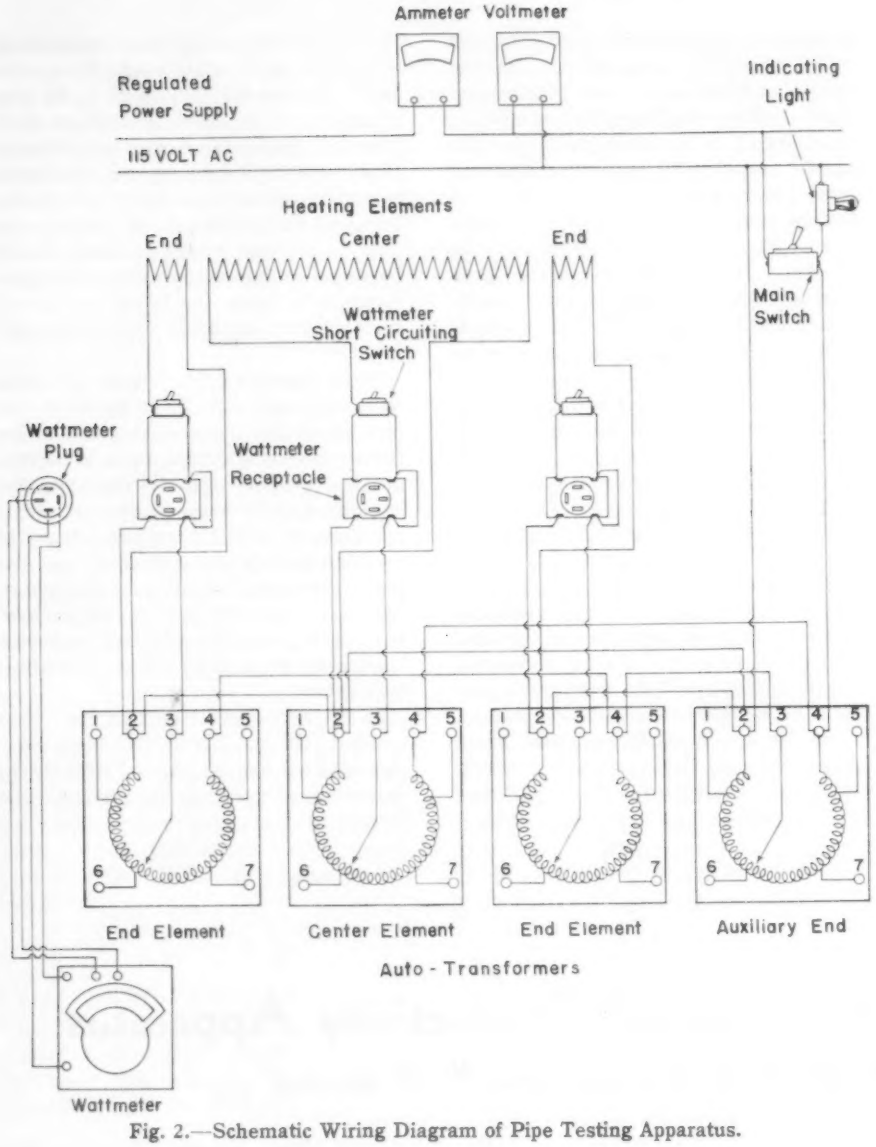


Fig. 2.—Schematic Wiring Diagram of Pipe Testing Apparatus.

ing elements. The center element covers the mid 30-in. section and the two end elements each cover a 3-in. section. The 2-in. pipe is centered in the 3-in. pipe and the ends are closed with Transite insulating disks. Standard sections of 3-in. pipe insulation, 36 in. long, are applied directly to this apparatus in accordance with the manufacturer's recommendations. The heat supplied to each element is regulated by means of an auto-transformer of the "Variac" type. The input to each element is adjusted until the temperature of the pipe over the end elements is the same as over the center element. When this occurs, it is assumed that the end losses are

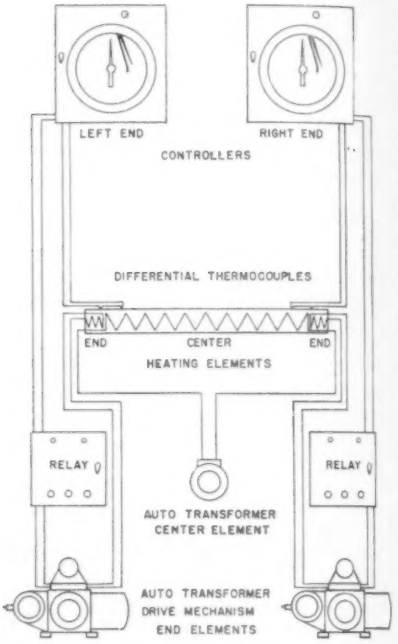


Fig. 3.—Automatic Control Diagram of Pipe Testing Apparatus.

bility of converting the apparatus from manual to automatic control. Various instrument companies were approached, and, after many ideas were promulgated, the instruments mentioned in this paper were purchased and put to use.

Description of Apparatus:

The apparatus to be converted from manual to automatic control were the pipe and the guarded hot plate conductivity apparatus that had been used for many years at the Station. Descriptions of the apparatus for use on alternating current follow.

Pipe testing apparatus.—The apparatus used for determining the thermal conductivity of pipe insulation is shown in Fig. 1, with a schematic wiring diagram in Fig. 2. As can be seen, inside of the 3-in. stainless steel pipe is an electrically insulated 2-in. stainless steel pipe around which are wound three heat-

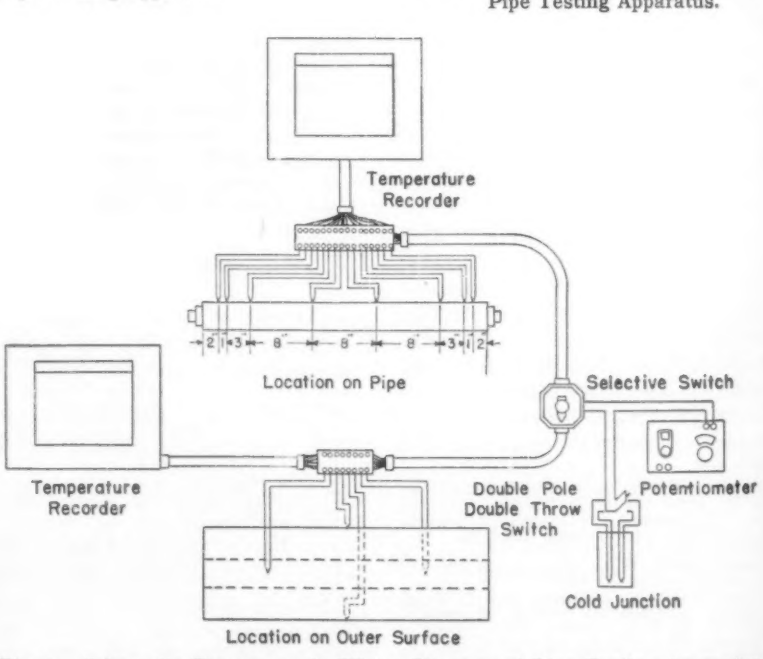


Fig. 4.—Schematic Thermocouple Wiring Diagram of Pipe Testing Apparatus.

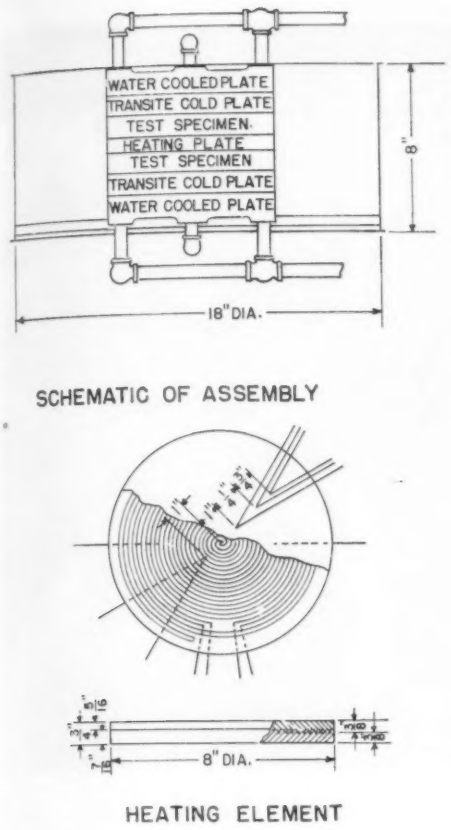


Fig. 5.—Guarded Hot Plate Test Apparatus.

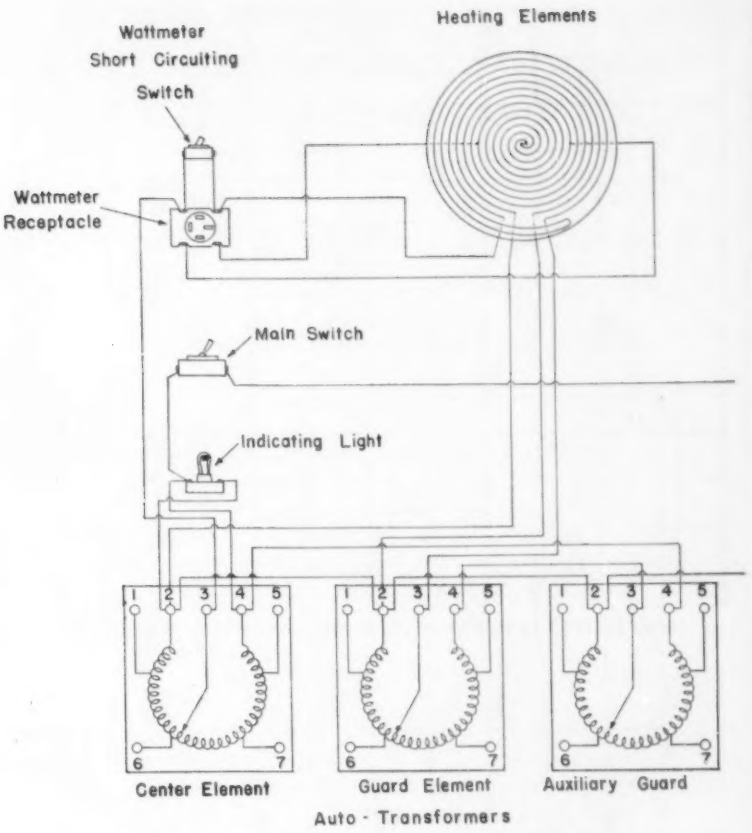


Fig. 6.—Schematic Wiring Diagram of Guarded Hot Plate.

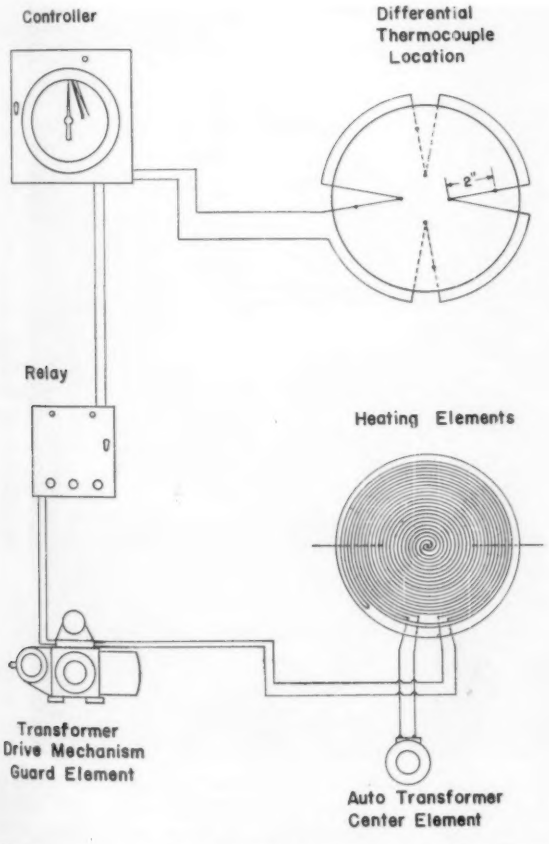


Fig. 7.—Automatic Control Diagram of Guarded Hot Plate.

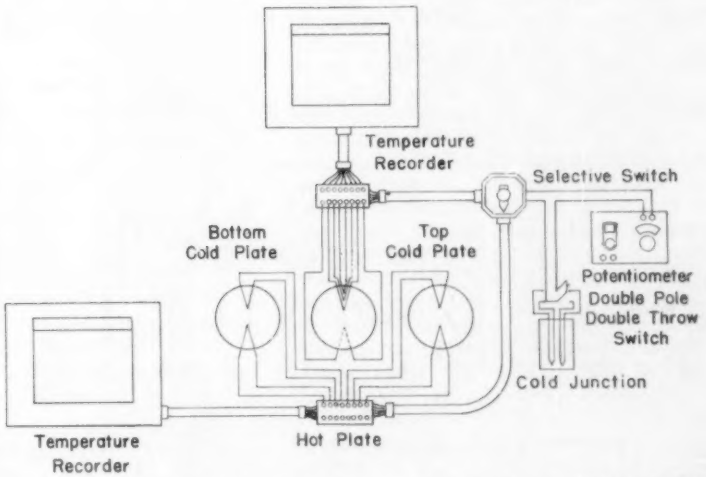
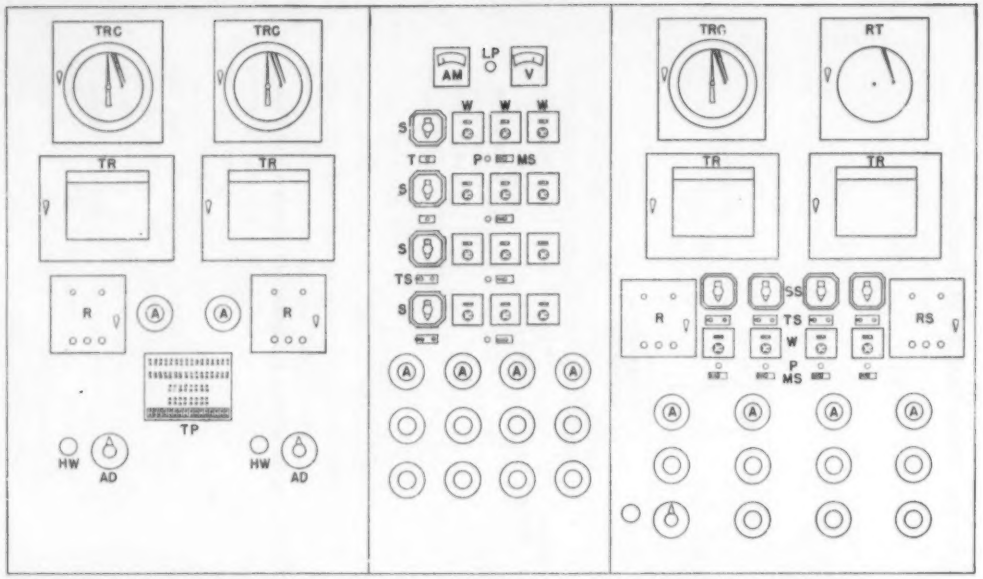


Fig. 8.—Schematic Thermocouple Wiring Diagram of Guarded Hot Plate.



TRC - TEMPERATURE RECORDER & CONTROLLER
TR - TEMPERATURE RECORDER
R - RELAY
TP - THERMOCOUPLE PLUG & JACK PANEL
AD - AUTO - TRANSFORMER DRIVE
HW - HAND WHEEL

AM - LINE AMMETER
V - VOLTMETER
LP - LINE PILOT LIGHT
P - TEST PILOT LIGHT
A - AUTO - TRANSFORMER
T - THERMOCOUPLE JACK

RT - RECORDING THERMOMETER
SS - THERMOCOUPLE SELECTIVE SWITCH
TS - THERMOCOUPLE SWITCH & JACK
W - WATTMETER SWITCH & RECEPTICLE
MS - CIRCUIT SWITCH
RS - RELAY SPACE FOR FUTURE USE

Fig. 9.—Panel Board.

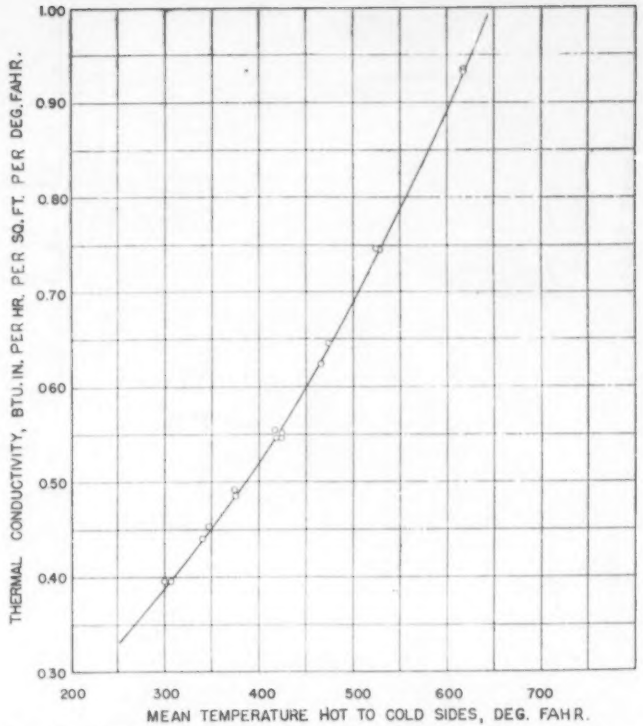


Fig. 10.—Thermal Conductivity of a Fibrous Material as a Function of Temperature.

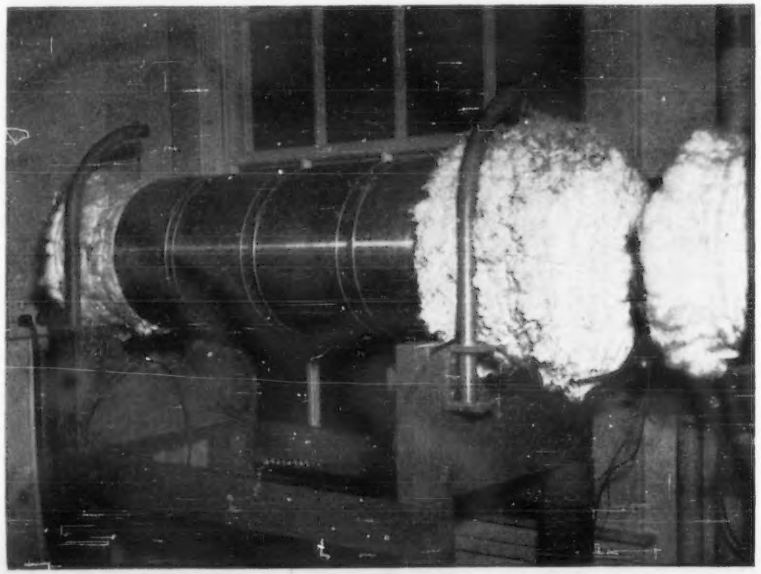
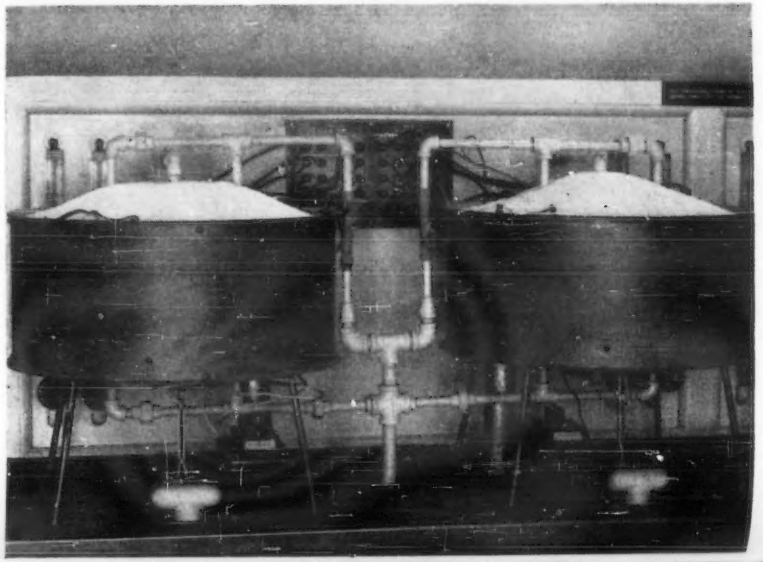


Fig. 11.—Pipe Testing Apparatus.



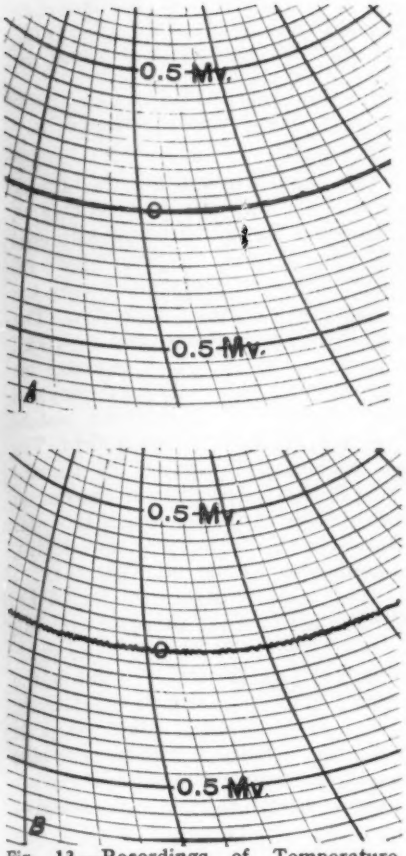


Fig. 13.—Recordings of Temperature Control in Pipe Testing Apparatus (*A*) and in Guarded Hot Plate Apparatus (*B*).

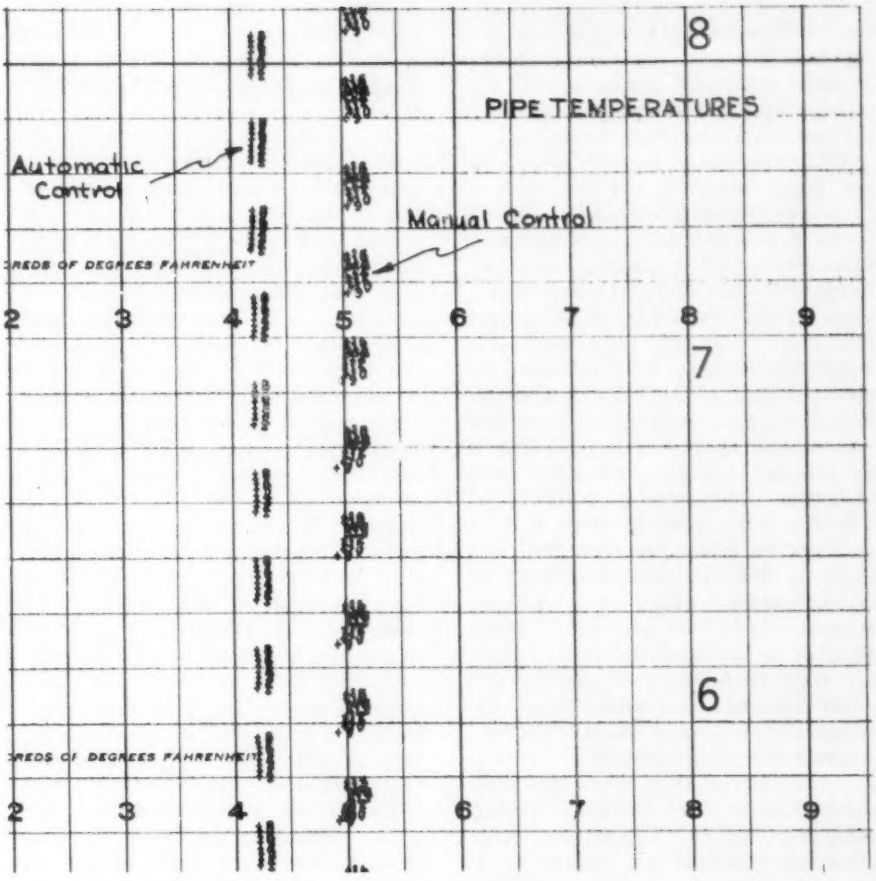


Fig. 14.—Recorded Pipe Temperatures.

compensated and the power supplied to the center element is dissipated as heat radially through the middle 30 in. of insulation. Temperatures of the pipe and outer surface of the insulation are measured by thermocouples. The input to the center element is measured directly with a wattmeter. With these measured values, the thermal conductivity of the insulation is calculable from known formulas.

During automatic operation, two differential chromel-alumel thermocouples (Fig. 3) are each used to indicate, control, and record in millivolts the heat balance between the center and end elements of the pipe apparatus. When an unbalance of temperature occurs between the heating elements, the resulting emf. actuates a Brown controller. The controller in turn sends an electrical impulse to a Beck relay detector which amplifies and relays the impulse to a motor-driven mechanism operating an auto-transformer in the proper direction to correct the unbalance by increasing or decreasing the input to the end elements. To increase the sensitivity of the control, an auxiliary "step-down" auto-transformer is connected in series with the auto-transformer of the end elements. This provides an increase in the voltage range and greater flexibility of control. The input of the center element is set to some predetermined amount by manual adjustment of the center element auto-transformer. Since a curve of thermal conductivities is required, it is not necessary to know the temperature which will result from this adjustment; however, experience with the apparatus has shown that the final temperature resulting from the initial manual setting can be closely approximated and, with practice, the thermal conductivity at any temperature can be determined without plotting a curve of conductivities. Figure 4 shows the thermocouple arrangement of the pipe testing apparatus.

Guarded hot plate apparatus.—For flat sections, such as blocks, and insulating cements, the thermal conductivity is determined in the guarded hot plate apparatus shown in Fig. 5.

The apparatus is similar to the National Bureau of Standards Alundum Plate and complies with A.S.T.M. Standard C 177–45. It consists of one $\frac{7}{16}$-in. and one $\frac{5}{16}$-in. round alundum plate, 8 in. in diameter, cemented together with heating elements located in the thicker plate to form a single $\frac{3}{4}$-in. heater plate. To each side of this heater plate is applied a 1-in. thickness of the material to be tested, 8 in. in diameter. Transite disks and water-cooled plates make up the finished apparatus. Granular diatomaceous earth is applied over the complete assemblage for further insulation. Electrical energy is supplied through two heating elements of commercially pure platinum wire—one heats the central 6-in. diameter area and the other the 1-in. outer periphery. Platinum-platinum 10 per cent rhodium thermocouples are installed at the top and bottom of the heater plate and at the cold surfaces of the test disks (Fig. 8). When the temperature across the face of the heater plate is constant at all points, it is assumed that all of the energy supplied is dissipated perpendicularly through the test area of the insulation being tested. To further minimize the effect of losses through the edges of the test disks, only the central 4-in. area of the disks and the heater plate are considered in calculating the conductivity. Figure 6 shows the wiring diagram of the guarded hot plate apparatus.

Automatic Regulation:

During automatic operation of this apparatus, four differential platinum-platinum 10 per cent rhodium thermocouples in series are used to indicate the direction of heat flow (Fig. 7). The emf. developed by any temperature difference between the center and the periphery of the heater plate actuates a Brown controller. The controller

Fig. 11.—Pipe Testing Apparatus.

sends the signal to the Beck relay detector which operates a mechanism and regulates the auto-transformer in the required direction. Again, as with the pipe apparatus, the energy supplied to the center coil is manually controlled.

While the inputs to both apparatus are being adjusted and balanced, a Brown temperature recorder is used to record 8 hot- and 4 cold-side temperatures for the pipe testing apparatus and 4 each of the hot- and cold-side temperatures for the guarded hot plate apparatus (Figs. 4 and 8). Wattmeter readings of the input to the center coils are obtained manually. To prevent excessive convection losses during tests, the pipe testing apparatus is housed in a temperature-controlled insulated room of a size approximately 8 by 12 ft. The apparatus is mounted on a dolly and can be easily removed from the room for refitting and attachment of thermocouples (Fig. 11). Clearly marked thermocouples, after being attached to the insulation to be tested, can then be fastened to permanently wired terminal boxes within the room. Excessive convection losses from the guarded hot plate apparatus are prevented by the addition of diatomaceous earth pellets over the assembled heating coils, etc. (Fig. 5). The input to both pieces of apparatus is controlled by a Superior Voltage Regulator, Model 1E5105.

Panel Board:

The U. S. Naval Engineering Experiment Station has four each of the pipe testing apparatus and the guarded hot plate apparatus. At present, however, only one of each type is automatically controlled. As can be seen in Fig. 9, there are four sets of short-circuiting switches and receptacles for use in measuring the watts input to the coils of each apparatus. In the case of the automatic equipment, manual selective switches are wired in parallel with all of the measuring thermocouples that are automatically recorded. This arrangement provides a means of manually checking the automatic equipment at any time. The panel board is constructed in three units—one for automatic control of the pipe testing apparatus, one for manual control of the pipe testing apparatus, and one for both automatic and manual control of the guarded hot plate test apparatus. These units are fastened together and so constructed that by simply disconnecting the power and thermocouple leads the panels may be moved to any location and reinstalled with a minimum of labor.

Two of the pipe testing apparatus are used for low temperatures, up to 600 F., and two for temperatures to 1600 F. One of the latter is automatically controlled. All of the temperatures of the 600-F. apparatus and the outside surface temperature of the 1600-F. apparatus are wired for iron-constantan thermocouples. All other thermocouples are chromel-alumel. In order to obtain as many recordings as possible on a 16-point iron-constantan recording instrument and to minimize the number of instruments required, a panel consisting of thermocouple plugs and jacks is provided (Fig. 9). With the use of this panel, it is possible to use the 16-point recorder for recording any combination of iron-constantan thermouples. Although the temperatures of only one pipe testing apparatus are automatically controlled, four outer-surface temperatures for each of two high-temperature apparatus and eight temperatures for each of the pipe- and outer-surface temperatures of two low-temperature apparatus can be recorded with one 16-point iron-constantan recorder. The hot plate test apparatus is suitable for temperatures to 1600 F. and is fitted with platinum-platinum 10 per cent rhodium thermocouples.

Test Data:

The data plotted on Fig. 10 are actual data obtained during the test of a fibrous type material. The duplication of data during heating or cooling of the apparatus is consistent. There is no doubt that the plotted results form a curved line. These results were calculated from the following formulas:

For the pipe testing apparatus:

$$k = \frac{q(r_1\ 2.303 \log r_2/r_1)}{A(t_1 - t_2)}$$

For the guarded hot plate apparatus:

$$k = \frac{qL}{A(t_1 - t_2)}$$

where:

k = thermal conductivity, Btu. in. per hr. sq. ft. deg. Fahr.,
t_1 = inner surface temperature of material, deg. Fahr.,
t_2 = outer surface temperature of material, deg. Fahr.,
r_1 = inside radius of pipe insulation, in.,
r_2 = outside radius of pipe insulation, in.,
L = thickness of block or fibrous material, in.,
q = heat loss, Btu. per hr., and
A = test area of heated surface, sq. ft.

The labor required for the attainment of the test data was less than 13 man-hours for the automatically controlled apparatus, but would have required 208 man-hours when using the old manual controlled apparatus. The time required for the manual controlled apparatus includes that required for constant surveillance during the day and the necessity of maintaining watch-standing personnel during the night. The calculations are based on the assumptions that equilibrium was reached in the shortest possible time; this was assured with the automatic apparatus, but not with the manual apparatus.

The precision of control for 24 hr. during the test of the above material can be seen in Figs. 13 and 14. The slight deviation from the control point on the chart, Fig. 13, is due to the comparatively low capacity of the guarded hot plate apparatus. With the high-capacity pipe testing apparatus, the trace of the set point on control is like a compass drawing.

Conclusions:

The apparatus has been in use for approximately one year. The total cost for materials, instruments, and labor for the wiring of eight sets, the building of two new high-temperature pipe testing apparatus and the panel board was $11,000. It is anticipated that the apparatus will be amortized in two years. This is based on the facts that the apparatus

1. Eliminates the need for watch-standing personnel during the night,
2. Can be used over the week-end when manual apparatus is usually secured,
3. Assists in the determination of data since equilibrium is reached more quickly at any one pipe temperature, because the end and center heating elements are always at thermal balance,
4. Can be used for research problems involving high convection losses (high air velocities) since it eliminates the need for constant surveillance and manual control, and
5. Leads to greater precision in the analyses of data, since replications can be obtained under electrically controlled conditions.

Study of Deformation at High Strain Rates Using High-Speed Motion Pictures*

By Herbert I. Fusfeld[1] and Josephine Carr Feder[1]

SYNOPSIS

This report describes a method for studying the geometry of deformation processes at drawing speeds using high-speed motion pictures. A shadow technique is used which permits measurements of strain and of the shape of the neck throughout a tension test at high speeds.

The method has been applied to obtain curves of the sharpness of the neck *versus* strain, data similar to that used by P. W. Bridgman to correct stress-strain curves for the true tensile stress once necking has set in.

The results of the preliminary tests have shown that:

1. Comparison of results for steel, aluminum and brass with results obtained by Bridgman in "static" tension tests shows that the true uniaxial tensile stress during tests at the speeds used (100 in. and 1000 in. per min.) is on the order of 5 per cent higher than would be calculated from Bridgman's results.
2. The change in formation of the neck as a function of the speed of test provides an indication of the manner in which strain-hardening varies with strain rate; steel and aluminum showed little change at 100 in. per min., more at 1000 in. per min., while brass showed considerable change at the first speed and little more at the faster speed.
3. The strain at which necking occurs tends to increase with increasing speed of test.

TO EVALUATE the suitability of metals for drawing, it is necessary to know their properties at strain rates encountered in such processes. This paper discusses the use of high-speed motion pictures in obtaining data on bar tension specimens pulled at high strain rates. The major purpose is to present the technique and to determine what quantitative data can be derived with it. As an example, the geometry of the neck is studied as a function of strain and strain rate, and the implications of such studies indicated.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

* Presented at the Fifty-third Annual Meeting of the Society, June 26–30, 1950.

[1] Physicists, Pitman-Dunn Laboratory, Frankford Arsenal, Philadelphia, Pa.

MATERIALS AND EQUIPMENT

Specimen Material:

Round bar specimens, 0.505 in. in diameter, 2.75-in. gage length and 4.75-in. total length, were used in tension tests. Materials tested were aluminum 24S-T, aluminum 75S-O, 70–30 cartridge brass, and cold-rolled S.A.E. 1020 steel.

Machines:

Three machines have been used for the tests to date. They include a Tinius Olsen testing machine (Fig. 1), crank press (Fig. 2), and a Denison hydraulic press.

To observe the behavior of the specimens under conventional conditions, a Tinius Olsen machine of 120,000-lb. capacity was used. This machine was operated at its highest speed of about 6 in. per min.

Tests designed to observe the behavior of specimens under speeds of drawing operations utilized a single-action crank press ordinarily used for drawing cartridge cases. A single downward stroke of this press travels at the rate of 14 in. per sec. However, the machine is not necessarily operat-

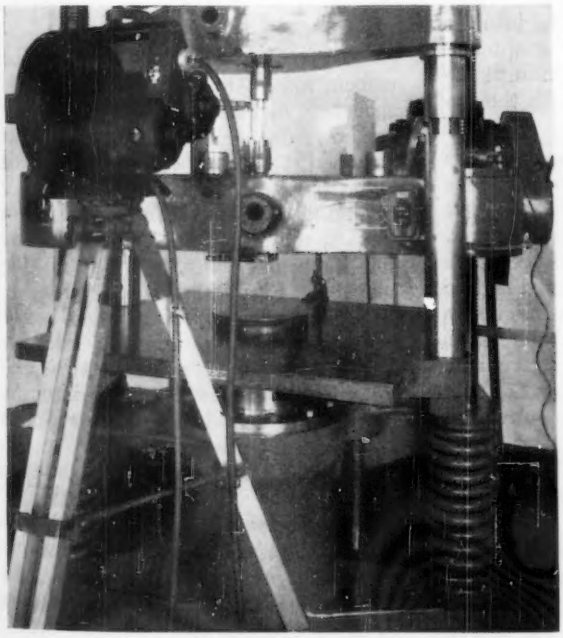


Fig. 1.—Arrangement of Camera, Specimen and Mirror in Standard Tension Machine.

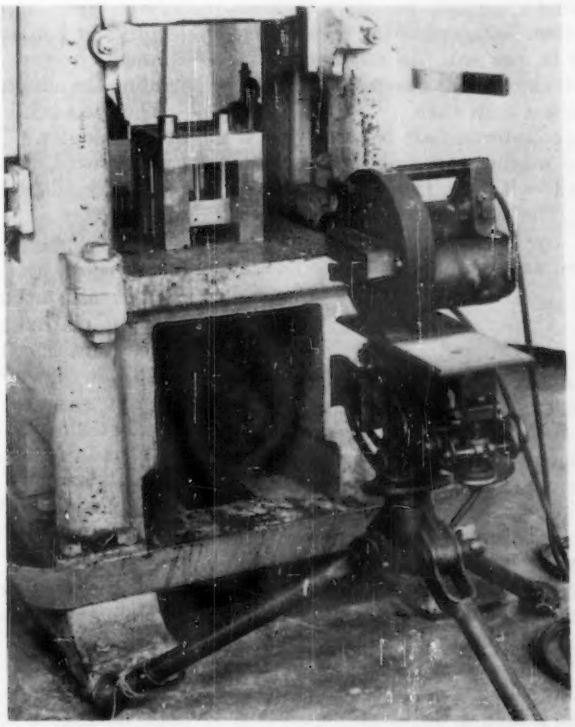


Fig. 2.—Arrangement of Camera and Special Fixture in Crank Press.

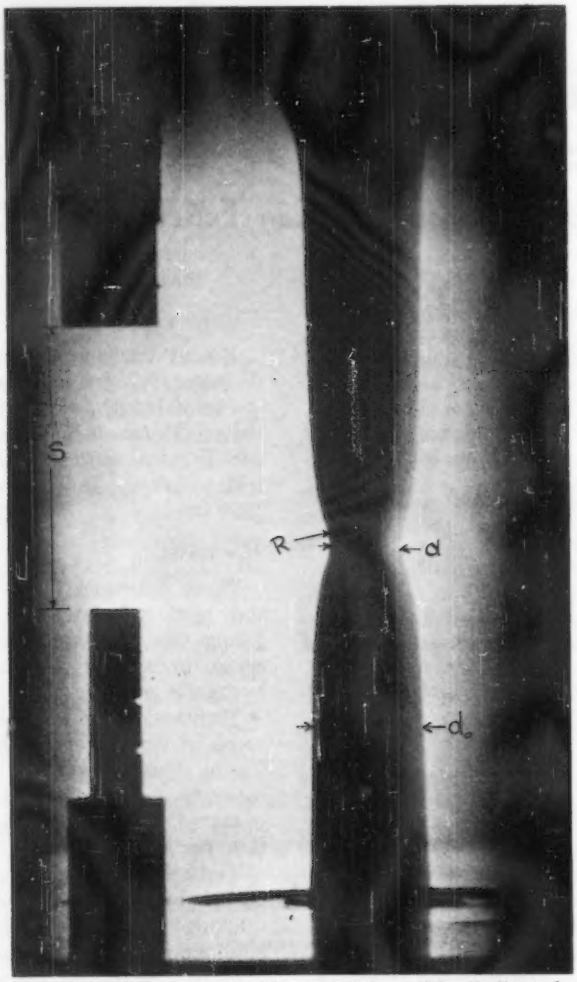


Fig. 3.—Typical Frame with Measured Quantities Indicated.
d = Least Diameter
d_o = Diameter Near End Point
S = Distance Between Gage Points
R = Radius of Curvature at Neck

ing at that speed at the time of fracture. One brass specimen, for example, fractured when the speed of the press stroke was 10 in. per sec. In any event, the press stroke, which covers 8 in., takes place in less than 1 sec.

A speed intermediate between that of the two machines described above was obtained with a Denison hydraulic press. The speed of this press is controlled by hand so it cannot be determined accurately prior to the test.

Fixture:

The crank press and hydraulic press could not be used for the tension tests until a special fixture was designed and constructed to hold the specimen. This fixture (Fig. 2) consists of two steel plates in which the specimen grips are placed. The upper plate is stationary; the lower is supported on springs. Attached to the lower plate are two hardened steel guide pins or posts which, when hit by the press ram, move the lower plate downward, causing the specimen to be pulled in tension. The specimen is held in ball-shaped adapters which prevent misalignment.

The lower adapter is held loosely in a permanent position by two steel pins. These pins, approximately 4 in. in length and $\frac{1}{4}$ in. in diameter, are slipped through grooves in the adapter, thus holding the adapter in place.

The specimen is first screwed into the lower adapter. The upper adapter is then screwed on the specimen until the top of the adapter is flush with the top of the fixture.

Total elongation of the specimen is measured by the use of two gage pins permanently attached to the top and bottom plates and axially aligned. These pins, one 0.40 in. and the other 0.20 in. in diameter, are tapered to fine edges at the ends. They were originally set at a distance of 0.025 in. before each test. It was found more convenient to set these pins permanently at their maximum separation. That obviated changing the gage position after every test.

On the smaller pin there are two notches, the bases of which are 0.2000 in. apart. This known distance between notches is used for the calibration of measurements of the distance between gage points during the course of deformation and of other quantities that might be measured.

Cameras and Film:

For the preliminary tests in the tension testing machine, a 16-mm. high-speed Fastax motion picture camera and reversal film were used. The camera can be run for 2 sec. at a maximum film speed of 3000 frames per sec., or for 3 sec. at 2000 frames per sec. This would not allow the complete process of deformation to be observed. For example, the 70–30 brass will break approximately 11 sec. after tension is begun. An effort was made to record the final stages of deformation and fracture of the specimen.

A 35-mm. Fastax camera and negative film were substituted when pictures were taken of the specimens in tension in the crank press and hydraulic press. The change in camera and film led to larger frames and sharper definition of the specimen and gage.

This camera records approximately $1\frac{1}{2}$ sec. of operation. This is sufficient to cover the complete deformation and fracture in the crank press and the latter stages of deformation and fracture in the hydraulic press. At the point of fracture the camera was operated at a film speed of 4000 frames per sec.

Method and Procedure

Optical Arrangement:

The lighting system found most satisfactory consisted of a 750-w. keg light placed behind the machine and a frosted-glass screen placed between the machine and light. This arrangement gave sharp contour pictures of the specimen viewed against the illuminated frosted-glass background.

It was thought desirable to observe the progress of deformation at right angles to that side seen by the camera. Therefore, a mirror was attached to the platform of the Tinius Olsen machine at an angle of 45 deg. to the camera axis. On the other side of the specimen, at an angle of 90 deg. to the camera axis, a 150-w. spot light was attached to the machine. Between this light and the specimen was another frosted-glass screen (Fig. 1). In this way shadow pictures were obtained simultaneously of two views of the specimen at right angles.

The use of a mirror was found not to be necessary to obtain the measurements described in this report; hence, no mirror was incorporated into the special fixture used with the crank press and hydraulic press.

Measurements:

Measurements were made of the 35-mm. pictures of specimens broken in the crank press and in the hydraulic press. These measurements were made by projecting the film through a S.V.E. (Society for Visual Education) still projector onto a large sheet of white paper.

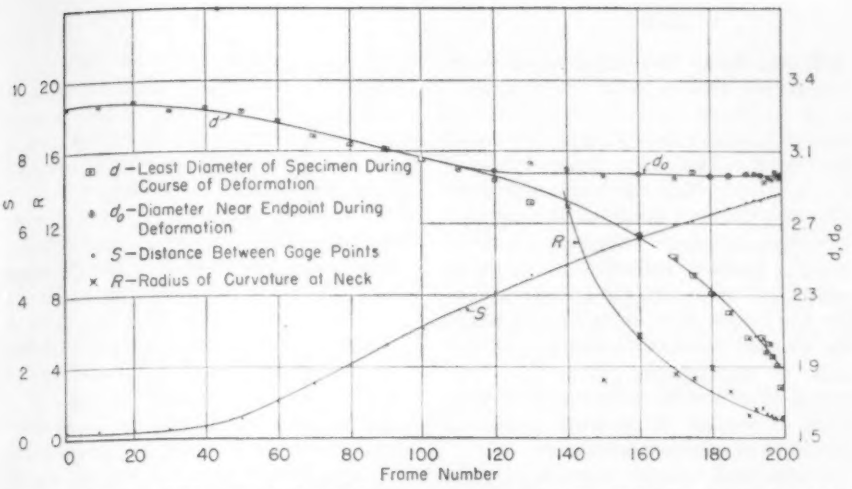


Fig. 4.—Curves of Measured Quantities *versus* Frame for 70–30 Brass at Speed of 110 in. per min.

The contours of the specimen and gage pins were traced on the paper. From these drawings, measurements were made of the diameter of the specimen in the necked region and near the end points, radius of curvature at the neck, contour of the necked region, and distance between gage points during the course of deformation. A typical frame is shown in Fig. 3 with the measured quantities indicated. Some detail has been lost in reproduction.

Method of Computation:

Each of the measured quantities is plotted *versus* frame number, as shown in Fig. 4 for one of the specimens tested. This has been done to eliminate scatter in each of the variables before computing the quantities used as described under "Results" below. Values are read from the smooth curves for desired frame numbers.

For the specimen represented by Fig. 4, the relation between frame number and strain is partially given as follows:

Frame	Strain
No. 140.....	0.36
160.....	0.51
180.....	0.76
190.....	0.94
195.....	1.07
200.....	1.20

Results

The primary use thus far of the technique described herein has been to check and extend the work of P. W. Bridgman in determining the stress distribution across the neck of a tension specimen. He has shown[2] that, to a reasonable approximation, this distribution is a function of the sharpness of the neck as measured by the ratio a/R where a = radius of narrowest cross-section, and R = radius of curvature of contour in the immediate region of neck.

[2] P. W. Bridgman, "The Stress Distribution at the Neck of a Tensile Specimen," *Transactions*, Am. Soc. Metals, Vol. 32, pp. 553-572 (1944).

Once necking has set in, the stresses acting on the narrowest cross-section are no longer uniaxial, except at the surface. The experimental value obtained by dividing the area of this cross-section into the load is therefore only an average value of tensile stress. The true uniaxial tensile stress at the surface is related to the average tensile stress by the expression:

$$S_{true} = \frac{S_{avg.}}{\left(1 + 2\frac{R}{a}\right) ln \left(1 + \frac{1}{2}\frac{a}{R}\right)}$$

To make it possible for the experimenter to correct his average tensile stress, once necking has set in, without measuring the radius of curvature, Bridgman has plotted a curve of a/R *versus* $ln\ A_0/A$, where the latter quantity is the natural strain, and A_0 = original cross-sectional area, and A = instantaneous area of narrowest cross-section.

The information obtained from the tests described in this report can be compared with Bridgman's data in three respects:

1. Bridgman used steels alone. This report covers several materials.

2. Bridgman's curve is an average of many experiments conducted with different specimens. For most of his measurements, the specimen was removed after necking set in and a single set of measurements made on it. Thus each point plotted represented a different specimen. The data obtained with the technique described in this report yield a curve showing the dependence of a/R on strain during the deformation of a single specimen. In this connection, Bridgman does state[3] that "in a number of cases the specimen was replaced and stretched further, without deviation from the general curve."

3. Bridgman's tests were conducted in tension machines operated at a rate of much less than 1 in. per min.[3] The data of this report were obtained at speeds 100 to 1000 times greater than these "static" tests.

The curves of a/R *versus* strain obtained to date are given in Fig. 5, along with the average curve obtained by Bridgman for steels. Several features of these curves are to be noted:

(*a*) All curves fall below that of Bridgman, except for the slower of the two curves obtained with steel. Even this lies below Bridgman's curve for strains greater than 0.4.

(*b*) The slopes of the pair of curves obtained for steel are approximately equal for increased values of $ln\ A_0/A$, as are the slopes of the pair of curves obtained for aluminum. The curve representing the faster speed lies below in both cases.

[3] Private communication from P. W. Bridgman, May 27, 1949.

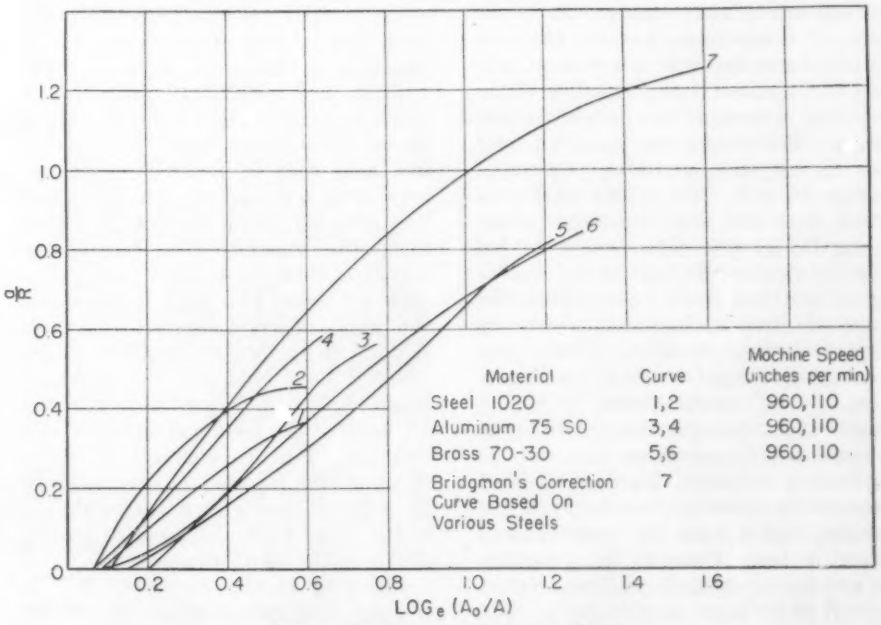


Fig. 5.—Curves of a/R *versus* Strain.

(*c*) The curves for brass, overlap in several regions and can be considered approximately the same within experimental error.

(*d*) The curves, including that of Bridgman, have slopes approximately equal, with values ranging from 0.8 to 1.2.

The curves of a/R *versus* strain given in Fig. 5 are computed from the data on d and R plotted in Fig. 4. The smooth curve for d represents the points shown to within 2 per cent. In the case of R, however, the example given in Fig. 4 indicates that the points from frame 200 to 195, that is, strains of 1.20 to 1.07, are represented by the smooth curve to less than 1 per cent error; from frames 195 to 160, that is, strains of 1.07 to 0.51 to about 2 per cent, neglecting one bad point at frame 180; below frame 160 to the point of necking, that is, for strains from 0.51 to 0.15, no reliable results are possible. Nevertheless, the strain at which R becomes infinite is known, as this is the point where necking begins, and hence the point at which the curve of a/R intercepts the axis is known. Thus, a smooth curve joining this known intercept to the region where reliable measurements exist should represent the actual behavior of the specimen to within approximately 5 per cent.

In general, then, for values of a/R greater than 0.2, the curves of Fig. 5 are accurate to within 3 per cent. As a/R increases toward the point of fracture, the total error is reduced to about 2 per cent, and near the region of necking, a/R decreasing, the total error increases to approximately 5 per cent.

Discussion

The prime purpose for obtaining the curves was to note whether the correction of stress-strain data for the true tensile stress would be adequate, if one used Bridgman's curve, regardless of the material or speed of test under consideration. Referring to Bridgman's paper[2] for the dependence of the correction factor on a/R, the curves of Fig. 5 show that the final calculated stress using Bridgman's curve would be too low by about 6 per cent in the case of brass, and from 3 to 5 per cent in the case of steel and aluminum at the higher testing speeds. These percentage deviations refer to the main portion of the curves shown, becoming higher at increasing strains and dropping to zero as a/R approaches zero.

From a different viewpoint, it is of interest to correlate the shape of the necked region with the material and speed of test. Consider the geometry of two specimens having different values of a/R at the same value of strain. The specimen having the smaller value of a/R, and hence the larger value of R, has a neck that extends over a greater axial distance from the point of minimum diameter. This is illustrated in Fig. 6. Thus, the zone of appreciable plastic flow is more extensive. This implies that strain-hardening near the edge of the neck was not sufficient to inhibit further deformation in that region. Conversely, the specimen having the larger value of a/R, and hence the smaller value of R, has a narrower zone of appreciable plastic flow, implying that strain-hardening was sufficient to localize deformation closer to the point of minimum diameter.

Bridgman's curve represents the "static" or isothermal case, in that temperature equilibrium was maintained throughout the specimen at all times by virtue of the slow strain rate and by keeping the specimen immersed in liquid.[3] Under these conditions, strain-hardening is expected to be complete and uniform, so that the subsequent plastic flow after instability sets in tends to be localized in a relatively small region about the point of minimum diameter.

At the higher testing speeds utilized in this investigation, the conditions are reasonably adiabatic, and the temperature does not remain constant. While no attempt was made to study the temperature variations, qualitative evidence indicating the rise in temperature was obtained by noting that the specimen pieces were warm when removed from the crank press after fracture. Since heat conduction through the metal grips occurred continuously, momentary temperatures may have been considerable. The material under these conditions would not harden to the same extent as in the static test. Thus, when instability sets in, plastic flow still continues to take place throughout a larger region than in the isothermal case.

From this qualitative discussion, it would be expected that at higher testing speeds deformation would not become localized, that is, necking would not begin until a greater uniform strain had been attained than in the very slow test. Since the material does not strain-harden sufficiently to limit plastic flow after instability to a small region about the neck, it could support a greater uniform strain before the effect of decreasing area balanced the effect of strain hardening. This has been noted for most of the tests conducted in this program. Further, engineering stress-strain curves reported in the literature for different speeds show the maximum of the curve to be displaced to greater strains as the speed increases.

Referring to the curves of Fig. 5, it is seen that speeds on the order of 100 in. per min. do not cause steel and aluminum to give results that differ appreciably from the static case, while brass shows a very decided effect. When speeds on the order of 1000 in. per min. are used, the steel and aluminum approach the curves for brass, while the results for brass are essentially the same as at the speed of 100 in. per min. One may conclude that strain-hardening of the more brittle steel and aluminum varies so slowly with test conditions that it is necessary to go to the higher speeds before achieving an extension of the region of plastic flow. For the more ductile brass, the strain-hardening process can be influenced at the lower speed so appreciably that little, if any, further change is produced by the higher testing speed.

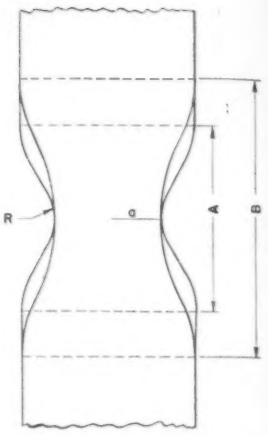


Fig. 6.—Contours Illustrating Two Values of a/R for Equal Strains.

It appears that a study of the geometry of deformation can provide information on the flow properties of materials not always obtainable from a simple stress-strain curve. This is particularly true at speeds equivalent to those used in drawing operations, as the shape of the neck is more sensitive to speed than the stress-strain curve itself.

There is the further possibility that these studies can be utilized for investigating the mechanism of fracture. The data in this report are insufficient to warrant an attempt to correlate geometry of deformation with fracture. However, the embrittling effect of a notch can be brought about by the presence of a neck, and hence a change in the geometry of the neck should alter this effect. Finally, the extent to which plastic flow is localized, as measured by the ratio a/R, should influence the strain at which fracture occurs.

Conclusions

This report has dealt with the development of a method for studying plastic deformation and an application of this method to certain features of the necking process in tension specimens. In conclusion, it may be stated that:

1. The shape of a neck and the strain in a tension specimen pulled at speeds used in drawing processes have been obtained throughout the test with high-speed motion pictures.

2. Comparison of results for steel, aluminum, and brass with results obtained by Bridgman in "static" tension tests, shows that the true uniaxial tensile stress during tests at the speeds used (100 in. and 1000 in. per min.) is on the order of 5 per cent higher than would be calculated from Bridgman's results.

3. The change in formation of the neck as a function of the speed of test provides an indication of the manner in which strain-hardening of the material varies with strain rate; steel and aluminum show little change at 100 in. per min., more at 1000 in. per min., while brass showed considerable change at the first speed, and little more at the faster speed.

4. The strain at which necking occurs tends to increase with increasing speed of test.

DISCUSSION

Mr. P. E. Cavanagh.[1]—Has any thought been given to the speed at which there would be no plastic deformation?

Mr. Herbert I. Fusfeld (*author*).—Our principal concern in this program was with materials used in deep drawing operations that would show considerable deformation. The strain rates investigated were those encountered in punch presses. Many other investigators have studied considerably faster rates of strain in recent years under impact conditions. Particularly active in this field have been Clark, Duwez, and von Kármán at California Institute of Technology.

[1] Assistant Director, Dept. of Engineering and Metallurgy, Ontario Research Foundation, Toronto, Ontario, Canada.

Mechanically Determining the Time of Set of Portland Cement by Means of the Spissograph

By O. J. Glantz[1] and L. E. Halsted[1]

Synopsis

In an effort to relieve an operator of the responsibility of intermittently checking time of set on cement samples, an automatic machine has been devised. The test results shown include both the conventional hand method *versus* the mechanical method, both on neat cement and mortar. The conclusion is that it is possible to do a satisfactory job of mechanically determining time of set, particularly on mortar samples.

In the physical testing of portland cement, it is important to determine if the cement will "set" or harden properly. At the present time there are two methods of testing time of set, the Gillmore method and the Vicat method,[2] both of which require frequent checking by an operator. To relieve the operator of this responsibility, a mechanical method of determining set has been devised.

The term "spissograph" has been applied to an automatic machine designed to determine the setting time of portland cement. The word "spissograph" is derived from "spiss" meaning thick, close, or dense, and "graph" which means that which is written. In effect then, the spissograph is an instrument used to show graphically the thickening or setting of portland-cement pastes or mortars.

Time of Set

At the present time, both ASTM and Federal specifications require two determinations of set, one being called initial set, and the other final set. The initial set should be not less than 45 min. with the Vicat method, or not less than 60 min. using the Gillmore test.[2] The purpose of this requirement is to eliminate any cement that has such a rapid set as to cause trouble in the initial mixing and placement of concrete.

Final set should be not longer than 10 hr. (This requirement is the same for both methods.) The purpose of this requirement is to obtain cements that will set within a reasonable time so that the forms may be stripped without unusual delay.

Recently, the ASTM Working Committee on Time of Set proposed that a 1:1 mortar rather than a paste should be used for determining time of set. The details of the proposed test were published in the Society's *Proceedings* for 1948.[3] Other significant departures from the present tests are that only one setting time is determined (rather than an initial and final set), and that the set is considered to have occurred at the time when the needle penetrates exactly 10 mm. This value is determined by interpolation from the actual readings. The apparatus used is the Vicat with a modified plunger and needle.

The Spissograph

The instrument used in this study was fabricated in the laboratory shops. It is a modification of the instrument, also known as the Cadograph, designed and made by W. J. Hodge, Works Manager for the Southern Portland Cement, Ltd., Berrima, N.S.W., Australia.[4] General views of the instrument are shown in Fig. 1. The setting times of four samples can be determined simultaneously, the pastes being placed in the cylindrical molds, and the needles lowered mechanically by a cam. The needles correspond in size and weight to the Vicat needle. The depth of penetration of each needle is recorded on a chart mounted on the drum.

A small motor turns the main shaft which is equipped with cams to (1) rotate the paste so that each penetration is into a new position of paste, (2) lower the needle on each sample at 10-min. intervals, and (3) move the recording drum a definite distance so each value may be properly recorded.

The principal modifications in this spissograph as compared to Mr. Hodges' model are (1) the enclosing of the samples in a watertight compartment and the incorporation of automatically controlled air jets that keep the humidity near 100 per cent, (2) the incorporation of automatic needle wipers which keep the needle clean, (3) the incorporation of another motor and a clutch arrangement to allow the needles to penetrate

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[1] Engineers, Bureau of Reclamation, Denver, Colo.

[2] Standard Methods of Test for Time of Setting of Hydraulic Cement by the Vicat or Gillmore Needles (C 191–49), 1949 Book of ASTM Standards, Part 3, p. 149.

[3] "Proposed Method of Test for Setting Time of Hydraulic Cement in Mortar," *Proceedings*, Am. Soc. Testing Mats., Vol. 48, p. 250 (1948).

[4] W. J. Hodge, "Determining the Setting Time of Portland Cement, Southern Portland Cement, Ltd., Apprentices Design New Automatic Instrument," *B. H. P. Review*, September, 1941.

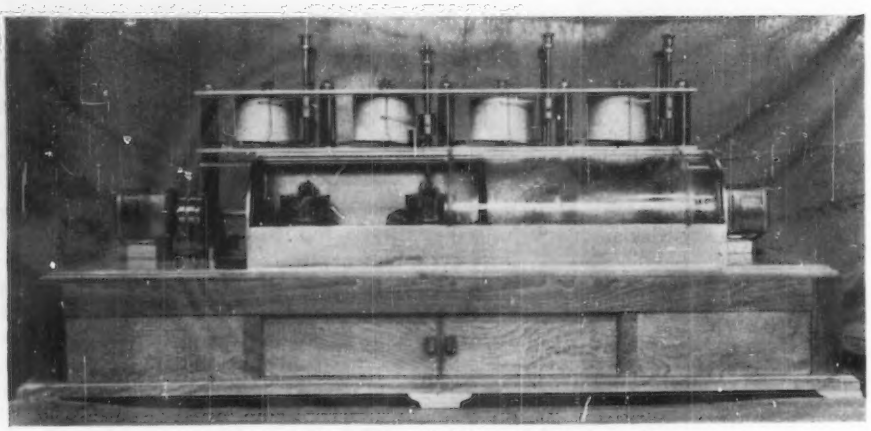


Fig. 1.—Front View of Modified Spissograph.

each sample at 1-min. intervals. This last provision was made so that the instrument could be used for special studies, such as premature stiffening.

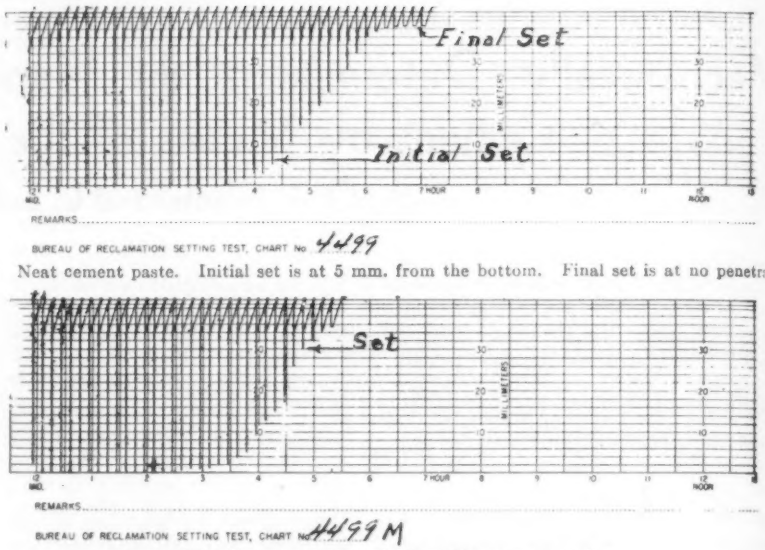
Discussion of Laboratory Tests

Two test series were run. These were: (1) tests on neat cement pastes, comparing the spissograph results with Vicat and Gillmore results, and (2) tests on cement mortars, comparing the spissograph with the new time of set test proposed to ASTM.

Tests on Neat Cement Pastes.

Although the spissograph is essentially a mechanical Vicat apparatus, it is not possible to use the time-of-set criteria exactly as defined in the Vicat test, which defines final set as the time of "no appreciable indentation." For this study, final set was taken as the time required to get two or more penetrations of the same depth, at the minimum reading. This is illustrated in Fig. 2(*a*), a reproduction of a chart from the spissograph.

Twenty-five cements were used, ten type I, seven type II, three type III, four type IV, and one type V. The results are shown in Table I and plotted in Figs. 3 and 4. As would be expected, the relationship for initial set is quite good between the spissograph and the Vicat. For the final set, however, the



(*a*) Neat cement paste. Initial set is at 5 mm. from the bottom. Final set is at no penetration.

(*b*) Cement mortar. Set is at 10 mm. penetration.

Fig. 2.—Spissograph Charts

criteria used for the spissograph has given consistently lower results, because it is possible to detect an appreciable indentation with the eye, which will not be recorded by the spissograph.

Final set by the Vicat, and both initial and final set by the Gillmore, are subject to considerable possibility of operator error in judging the time of "no appreciable indentation." These errors are enhanced by differences in lighting and surface conditions.

Tests on Cement Mortars:

The proposed ASTM setting test is readily adapted to the spissograph by using a needle corresponding to the prescribed size and weight. The results of the mortar test[2] are shown in Table II, which includes, for comparison, the initial sets on the pastes as determined by the Vicat[3] and the spissograph. The mortar tests are plotted in in Fig. 5, which shows the good correlation obtained between the two mortar methods. A typical chart from a mortar test on the spissograph is shown in Fig. 2(*a*).

TABLE I.—SETTING TIMES OF NEAT CEMENT PASTES.[a]

Laboratory	Initial			Final		
	Vicat	Gillmore	Spissograph	Vicat	Gillmore	Spissograph
Type I Cement						
No. 4476	2:40	3:00	2:30	5:00	5:30	4:00
No. 4477	2:25	4:00	2:00	5:20	5:45	4:00
No. 4478	3:00	3:10	2:50	5:40	6:00	4:50
No. 4479	2:50	3:10	2:40	6:15	5:30	4:10
No. 4480	1:40	1:55	2:10	4:40	4:40	4:30
No. 4481	3:10	3:55	3:40	6:25	6:25	5:00
No. 4482	1:50	1:50	2:10	4:20	4:20	4:50
No. 4483	1:45	2:45	2:40	4:15	4:55	5:00
No. 4484	3:00	3:30	3:00	5:30	6:00	5:00
No. 4485	2:40	3:15	3:10	5:30	5:30	4:40
Type II Cement						
No. 4486	3:05	4:00	2:30	...	...	...
No. 4487	3:40	4:10	3:00	6:40	5:00	5:50
No. 4488	3:15	4:20	3:00	6:00	6:30	4:40
No. 4489	2:30	2:55	2:30	5:40	4:10	4:50
No. 4490	2:55	3:40	2:20	4:55	5:25	5:00
No. 4491	3:00	3:30	3:00	8:00	6:30	6:10
No. 4500	3:15	4:25	3:30	9:10	8:40	6:40
Type III Cement						
No. 4492	1:25	2:55	1:40	5:30	5:30	5:00
No. 4493	2:50	3:20	2:50	5:05	5:40	4:30
No. 4494	2:40	3:30	2:10	5:10	5:40	3:40
Type IV Cement						
No. 4495	3:15	2:50	3:10	6:45	6:15	5:50
No. 4496	4:25	4:55	4:30	7:50	8:30	6:40
No. 4497	4:05	4:30	4:00	7:50	7:05	6:50
No. 4498	4:20	5:25	4:00	8:25	9:25	6:30
Type V Cement						
No. 4499	5:20	5:20	4:30	9:35	9:05	7:10

[a] Time in hours and minutes.

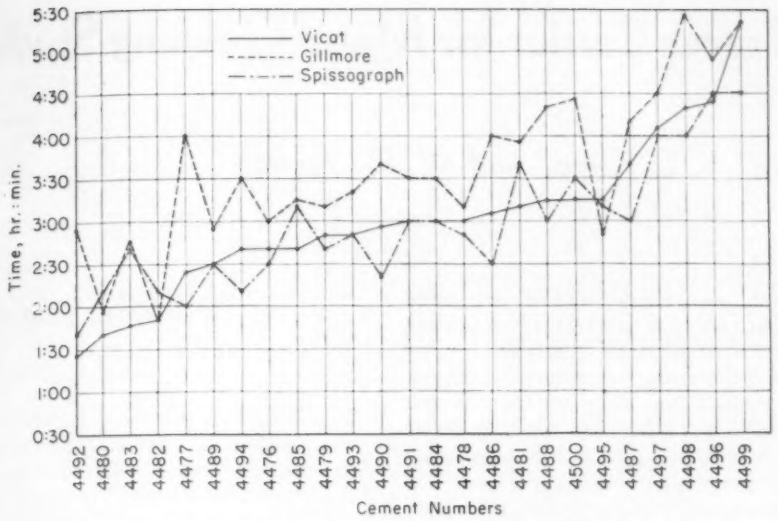


Fig. 3.—Initial Time of Set as Determined on Cement Pastes.

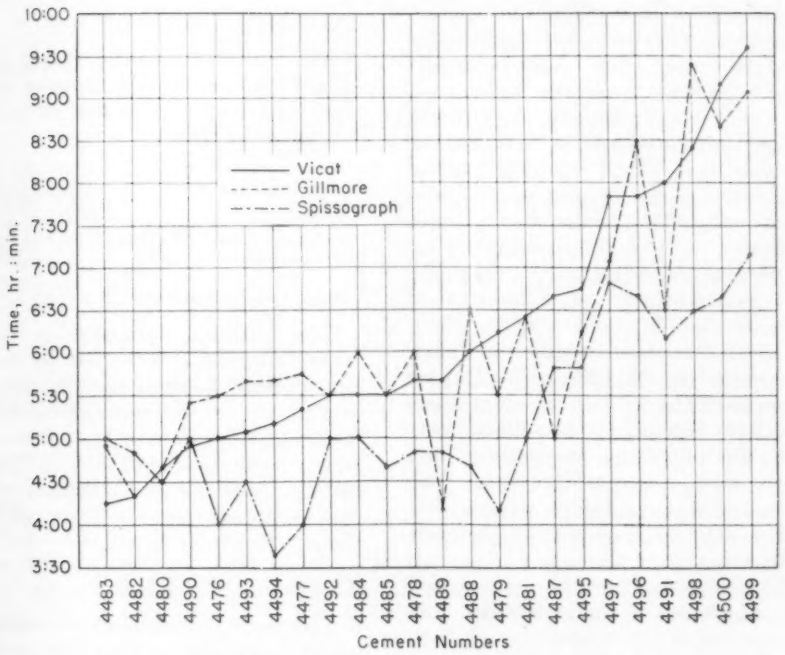


Fig. 4.—Final Time of Set as Determined on Cement Pastes.

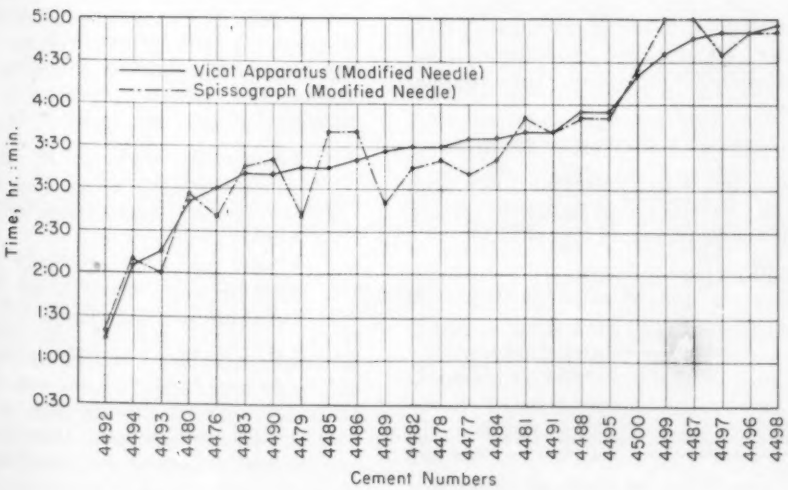


Fig. 5.—Time of Set as Determined on Cement Mortars.

TABLE II.—COMPARISON BETWEEN SETTING TIME AS DETERMINED ON PASTES AND MORTARS.[a]

Cement	Initial on Paste		Mortar Test	
	Vicat[a]	Spisso-graph	Vicat[a]	Spisso-graph
Type I				
No. 4476	2:40	2:30	3:00	2:40
No. 4477	2:25	2:00	3:35	3:10
No. 4478	3:00	2:50	3:30	3:20
No. 4479	2:50	2:40	3:15	2:40
No. 4480	1:40	2:10	2:50	2:55
No. 4481	3:10	3:40	3:40	3:50
No. 4482	1:50	2:10	3:30	3:15
No. 4483	1:45	2:40	3:10	3:15
No. 4484	3:00	3:00	3:35	3:20
No. 4485	2:40	3:10	3:15	3:40
Type II				
No. 4486	3:05	2:30	3:20	3:40
No. 4487	3:40	3:00	4:45	5:00
No. 4488	3:15	3:00	3:55	3:50
No. 4489	2:30	2:30	3:25	2:50
No. 4490	2:55	2:20	3:10	3:20
No. 4491	3:00	3:00	3:40	3:40
No. 4500	3:15	3:30	4:20	4:25
Type III				
No. 4492	1:25	1:40	1:15	1:20
No. 4493	2:50	2:50	2:15	2:00
No. 4494	2:40	2:10	2:05	2:10
Type IV				
No. 4495	3:15	3:10	3:55	3:50
No. 4496	4:25	4:30	4:50	4:50
No. 4497	4:05	4:00	4:50	4:35
No. 4498	4:20	4:00	4:55	4:50
Type V				
No. 4499	5:20	3:20	4:35	5:00

[a] Time in hours and minutes.

From these results, it is apparent that set, as determined by the mortar test, corresponds more nearly to initial set than to final set on the pastes. However, a study of available spissograph charts shows that the point of no penetration is reached rather quickly after the 10-mm. penetration point.

Conclusions

As a result of this study, it is concluded that the spissograph is a practical instrument for mechanically determining setting time. Results agree well with the Vicat test for initial set, although they give somewhat lower final sets. Agreement with the Gillmore test is reasonably good for initial set, and again somewhat lower for final set.

The new mortar setting test, recently proposed to ASTM is readily adapted to the spissograph. The results obtained using the spissograph were in good agreement with the method proposed to ASTM.

The spissograph eliminates much of the human factor in the time-of-set test, as well as the time required for an operator to make frequent penetration checks. It provides results on slow-setting cements requiring more time than the usual working day and provides a permanent record for the files.

Detailed drawings of the spissograph an available upon request. Inquiries should be sent to the U. S. Bureau of Reclamation Denver, Colo.

Improved Radioactive-Tracer Carrier for Metal Cleaning Studies

By J. C. Harris,[1] R. E. Kamp,[1] and W. H. Yanko[1]

OUR previous paper on this subject[2] described the use of a radioactive tracer compound containing carbon 14 as a means for measuring the cleanliness of a metal surface. Previous methods for determining cleanliness have been qualitative rather than quantitative and are represented by the water break method, the use of a fluorescent dye which if not completely removed is observable under ultraviolet light, and a copper dip method which with ferrous metals shows lack of cleanliness when the plate is either nonadherent or is dull. In most metal cleaning operations, complete cleanliness is desired to prevent such defects as a nonadherent electrodeposit or for operations where very minute capillaries are to be cleaned. A quantitative method for measurement of soil retention or removal has not been available but at the same time did not appear essential because in many instances a metal surface either is clean or, if *any* soil is retained, is dirty: Points midway between these extremes appeared of minor significance.

The presence of chemisorbed material on metal surfaces has long been suspected as the causative agent in poor electroplating, but the usual methods for investigation of lack of cleanliness did not provide sufficient sensitivity to detect these materials. Our previous paper showed that the sensitivity of the radioisotopic method was 2×10^{-7} g. per sq. cm. and that extent or lack of cleanliness between this limit and the initial soil could be measured quantitatively.

The radioisotopic tracer compound previously used, N,N-di-*n*-butyl stearamide, proved to be extremely difficult to remove and it was believed that this difficulty was because of chemisorption. Another difficulty with this particular tracer compound was that it was not entirely soluble in the oily soil used.

This paper discusses the use of an oil-soluble tracer compound which is not chemisorbed and compares the results with those obtained using N,N-di-*n*-butyl stearamide. The compound chosen for this work was *n*-undecane since this could be synthesized fairly readily by usual laboratory techniques to include an atom of carbon 14. Ideally, it would have been desirable to use a hydrocarbon in the range ordinarily present in lubricating oil, but it is extremely difficult to obtain such a compound in the pure state which would be sufficiently easy to process.

Although *n*-undecane has an appreciable vapor pressure, requiring that the work be performed in a hood because of health considerations, the vapor pressure was not sufficiently high under proper test procedure so that residual nonvolatile soil might remain undetected as a result of vaporization of the tracer compound. To obviate this possible difficulty, the time consumed in the actual evaluation operation was minimized and standardized. The process of chemisorption in the case of the stearamide product was extremely rapid since it occurred in the time normally used in applying the soil. In the cases where excellent cleaning compositions were used, the *n*-undecane was removed in a single wash, whereas the amide soil, under the same conditions, required two and sometimes more washes for complete removal.

The scheme of operation was to soil the pans with the soiling medium containing radioactive *n*-undecane or N,N-di-*n*-butyl stearamide, carefully spreading it over the pan surface, determine the initial count, submit the pan to the standardized cleaning operation, dry it under standardized conditions, and immediately determine the residual count.

Preparation of Radioactive Undecane:

The following synthesis[3, 4] was used for the preparation of radioactive undecane containing one atom of C 14:

$$n\text{-}C_{10}H_{21}MgBr + C^{14}O_2 = n\text{-}C_{10}H_{21}C^{14}O_2MgBr \quad (1)$$

$$4n\text{-}C_{10}H_{21}C^{14}O_2H + 3LiAlH_4 = (n\text{-}C_{10}H_{21}C^{14}H_2OH)_4LiAl + 2LiAlO_2 + 4H_2 \quad (2)$$

$$n\text{-}C_{10}H_{21}C^{14}OH + HI = n\text{-}C_{10}H_{21}C^{14}H_2I + HOH \quad (3)$$

$$4n\text{-}C_{10}H_{21}C^{14}H_2I + LiAlH_4 = 4n\text{-}C_{10}H_{21}C^{14}H_3 \quad (4)$$

The hydriodic acid used in reaction 3 contained 60 per cent HI. The synthesis was performed with 37.7 mg. of $BaCO_3$ (4.35 per cent C 14) and a 44.8 per cent radiochemical yield was obtained (0.5 millicurie of C 14).

Preparation of Soil:

The soil was prepared of the same composition as in the previous paper with the exception of the radioactive tracer compound:

	Per cent by Weight
S.A.E. No. 60 lubricating oil[5]	97
Fluorescent Green HW (175 per cent)[6]	2
n-Undecane	1

Cleaning Compositions Tested:

The cleaning compositions tested were comprised of 5 per cent by weight of a dodecyl benzene sodium sulfonate and 95 per cent of commercial sodium metasilicate pentahydrate, tetrasodium pyrophosphate anhydrous (TSPP), or sodium orthosilicate. Distilled water was used in the preparation of all solutions.

Experimental Procedure:

Five replicate pans for each test were soiled as described in our previous paper and were cleaned for each compound and solution concentration used. Approximately 25 mg. of soil were applied to a pan, the initial count made and the pan cleaned immediately following the count. The cleaning cycle was the same as that used and reported before:

1. Five-minute wash in 40 ml. of cleaning solution at a rolling boil.
2. Six dips into each of two boiling distilled water rinses.
3. Rinsed again under slowly running tap water about 30 sec.
4. Dried under a heat lamp.

The data in Tables I and II are shown as counts per minute before and after cleaning. When making the initial count on the contaminated pans, a second background count was made about

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[1] Monsanto Chemical Co., Dayton, Ohio.

[2] J. C. Harris, R. E. Kamp, W. H. Yanko, "Application of the Radioactive Tracer Technique to Metal Cleaning," ASTM BULLETIN, No. 158, May, 1949, pp. 49–52.

[3] R. F. Nystrom and W. G. Brown, "Reduction of Organic Compounds by Lithium Aluminum Hydride. II. Carboxylic Acids," *Journal*, Am. Chemical Soc., Vol. 69, pp. 2548–2549 (1947).

[4] Guyer, Bieler, and Hardmeier, "Darstellung Hohermolekularer Alkylhalogenide," *Helv. Chim. Acta.*, Vol. 20, pp. 1462–1467 (1937).

[5] Standard Oil Co. of Ohio.

[6] Wilmot & Cassidy, Inc., Brooklyn, N. Y.

TABLE I.—COMPARISON OF AMIDE AND UNDECANE TRACER COMPOUNDS.

Cleaning Solution Composition: 5 Per cent Dodecyl Benzene Sodium Sulfonate; 95 Per cent Alkaline Salt

Alkaline Salt	Tracer Compound	Pan No.	Counts per min.			
			Background	Initial (Thousands)	First Wash	Second Wash
Metasilicate	Amide	18	20.4 ± 1.3	25.8	32.4 ± 1.7	29.0 ± 1.6
		27	23.0 ± 1.4	37.6	106.0 ± 3.1	35.4 ± 1.8
		28	24.0 ± 1.5	35.5	45.0 ± 2.0	29.2 ± 1.6
		29	22.2 ± 1.4	36.7	56.0 ± 2.2	25.2 ± 1.5
		30	26.0 ± 1.5	36.8	51.0 ± 2.1	27.0 ± 1.6
	Undecane	75	21.4 ± 1.4	46.7	21.4 ± 1.4	17.2 ± 1.2
		76	16.6 ± 1.2	47.6	23.1 ± 1.4	16.4 ± 1.2
		77	14.0 ± 1.1	50.1	27.0 ± 1.5	17.4 ± 1.2
		78	16.0 ± 1.2	50.5	19.6 ± 1.3	17.4 ± 1.2
		79	19.0 ± 1.3	51.3	18.4 ± 1.3	17.6 ± 1.2
TSPP	Amide	52	25.8 ± 1.5	44.2	113.8 ± 3.2	49.2 ± 2.1
		53	24.0 ± 1.5	42.6	152.0 ± 3.7	39.8 ± 1.8
		54	26.4 ± 1.5	39.8	459.0 ± 6.4	49.8 ± 2.1
		55	27.8 ± 1.5	42.7	156.6 ± 3.8	44.0 ± 2.0
		49	26.6 ± 1.6	39.9	242.8 ± 4.7	66.6 ± 2.4
	Undecane	110	17.2 ± 1.2	50.5	20.8 ± 1.4	.....
		111	18.8 ± 1.2	50.8	60.6 ± 2.3	37.8 ± 1.8
		113	18.2 ± 1.3	49.3	19.6 ± 1.3	.....
		114	17.8 ± 1.3	52.9	43.8 ± 2.0	19.6 ± 1.3
		115	18.2 ± 1.3	51.1	53.0 ± 2.2	31.4 ± 1.6
Orthosilicate	Amide	67	26.4 ± 1.5	42.8	77.4 ± 2.6	29.4 ± 1.6
		68	22.2 ± 1.4	41.7	164.4 ± 3.8	39.2 ± 1.9
		69	30.0 ± 1.6	44.6	106.4 ± 3.1	39.0 ± 1.9
		70	27.8 ± 1.6	44.2	80.8 ± 2.7	35.8 ± 1.8
		71	24.4 ± 1.5	44.1	324.8 ± 5.4	34.6 ± 1.8
	Undecane	85	18.6 ± 1.3	48.5	19.2 ± 1.3	15.6 ± 1.2
		86	20.0 ± 1.4	51.0	19.4 ± 1.3	16.6 ± 1.2
		87	20.8 ± 1.4	51.1	19.8 ± 1.3	17.5 ± 1.3
		88	19.8 ± 1.3	49.4	21.0 ± 1.4	.....
		89	18.6 ± 1.3	31.2	18.0 ± 1.3	.....

TABLE II.—COMPARISON OF AVERAGE DATA FOR RADIOACTIVE SOILS.

Alkaline Salt	Amide Soil			Undecane Soil		
	Background	First Wash	Second Wash	Background	First Wash	Second Wash
Metasilicate	23.1	46.1	29.1	17.4	21.9	17.2
TSPP	25.9	140.8	45.7	18.0	39.6	29.6
Orthosilicate	26.6	112.2	35.6	19.6	19.5	16.6

5 min. after taking the initial count on the pan containing the undecane soil. Although this was necessary because of danger of contaminating the counter with the volatile undecane, it seldom showed contamination. Any pan giving a count above background was considered unclean, the goal being absolute cleanliness.

Discussion of Results:

It might be thought that volatilization of the radioisotopic *n*-undecane caused the pans to appear clean simply because it had been volatilized. The fact was, however, that with poor cleaning compositions, the radioactive soil was still retained after two washes, indicating its relatively low degree of removal through volatilization. This low degree of removal might be interpreted as chemisorption were it not for the fact that good cleaning compositions resulted in removal in a single wash. This was not true for the amide soil which even with good cleaning compositions was partially retained for at least two and in some cases up to five washes. Neither the amide nor undecane is ideally suited for tracer work of this type, the amide because of low solubility in oil and chemisorption characteristics, and the undecane because of volatility. Another difficulty with *n*-undecane is its high fluidity as compared with the higher hydrocarbons of lubricating oil, permitting relatively greater ease of removal. However, both radioactive compounds serve to define the utility of cleaning compounds and the method certainly is more quantitative and sensitive than any heretofore available. Unfortunately, no means for applying the method to plant control has as yet been developed, and it still remains a research tool.

Disintegration counts with the amide soil were made with a Geiger-Müller tube having a 2.4 mg. per sq. cm. mica window, and because replacement of the tube became necessary, a tube having a 1.4 mg. per sq. cm. mica window was used for the undecane soil. Although the thinner window tube should have proved more sensitive, this was not the case and it proved two-thirds as sensitive. Since the geometry and other physical variables were identical, the reason for this was unknown, unless it can be accounted for either by tube construction or a window thickness greater than was claimed. This difference in tubes is a partial explanation for apparent discrepancy in counts between the results obtained with the two tracer compounds.

Examination of Table I will show that the counts after wash were rather erratic in most cases. With the amide soil it should be noted that the wash test results with the silicates are fairly uniform and that for tetrasodium pyrophosphate the variation is greater. However, the variation with the undecane soil was considerably less, but again, is better with the silicate than with tetrasodium pyrophosphate.

It is apparent from this table that the average final count for the amide soil is greater than the corresponding count for the undecane soil. This shows the effect of chemisorption and, perhaps in part, the reduction in count with the undecane soil as a result of volatility. The difference in sensitivity of the counting tubes used will also account for some of the differences in the disintegration levels noted in the two sets of readings.

It is interesting to note that the chemisorption effect of the amide is more pronounced in the first wash, although some slight chemisorption for the radioactive undecane is likewise indicated because the average count after the first wash, in a number of instances, is still slightly above background. An alternative and more reasonable explanation is actual lack of soil removal in a single wash, particularly as evidenced by the TSPP compositions. Using the undecane soil as a criterion it would appear that a cleaner surface is obtained with sodium orthosilicate than is obtained with the sodium metasilicate type composition.

Table II shows a comparison of the average data for the three compositions in question. In cases where effective cleaning is obtained, the background count is equaled by the second wash in the effective cleaning materials such as the silicates. It should be noted that a poorer degree of cleaning results with the TSPP composition, indicating that residual count is attributable to residual soil held mechanically rather than by adsorption.

Conclusions:

The radioisotopic method under the conditions observed appears successfully to differentiate between types of cleaning compositions. This work indicates that the N,N-di-*n*-butyl stearamide tracer compound is definitely chemisorbed, while *n*-undecane appears to be adsorbed to a lesser extent. A preferable tracer would be a tagged hydrocarbon of a carbon chain length approaching that of the lubricating oil used as the soiling medium, probably in the range of 20 to 30 carbon atoms in length. Such a tracer compound should obviate the chemisorption difficulties of the amide soil and the volatility of the undecane soil.

ASTM Bulletins—1950

Subject Index Papers, Reports, and Articles*

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Index to Authors of Technical Papers

1950 ASTM Bulletins

Basic Law Creating National Bureau of Standards Extensively Amended

PUBLIC Law 619, approved July 22, 1950, defines and describes the authorized functions and activities of the National Bureau of Standards. It makes clear and explicit the legal basis for the activities of the National Bureau of Standards. The law is primarily an amendment to Section 2 of the Act of March 3, 1901, which established the Bureau.

The primary purposes for which the Bureau was established were to provide a basis for accurate measurements in this country and a source of information regarding basic properties of materials determined by such measurements. However, there arose almost immediately occasions for the practical application of these primary services to meet needs of the Government and of industry which were not foreseen, or at least not explicitly mentioned, in the original 1901 Enabling Act. Consequently within a few years the Congress made specific appropriations for activities which could only be covered by a broad interpretation of the clause, "the solution of problems which arise in connection with standards."

Among such activities, testing of materials and supplies purchased by the Government and the preparation of specifications for such materials early became important parts of the Bureau's duties although the Act of 1901 contains no reference to such service. During a period of 25 years beginning in 1910 the Congress provided specific funds for many additional lines of work in the Bureau without making the basic statutory authorization more explicit. These special items were repeated from year to year in appropriation acts up to 1935. Since then annual appropriation acts have specified that the funds provided were intended to cover the functions set forth in detail in the 1935 act. The new law gives explicit legislative authority in place of such reference to an appropriation act based upon interpretations of the Act of 1901.

In accordance with general policy the new act assigns functions to the Secretary of Commerce. The act prescribes six functions in general terms, as follows:

1. The custody, maintenance, and development of the national standards of measurement, and the provision of means and methods for making measurements consistent with those standards, including the comparison of standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the Government.

2. The determination of physical constants and properties of materials when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere.

3. The development of methods for testing materials, mechanisms, and structures, and the testing of materials, supplies, and equipment, including items purchased for use of Government departments and independent establishments.

4. Cooperation with other governmental agencies and with private organizations in the establishment of standard practices, incorporated in codes and specifications.

5. Advisory service to Government agencies on scientific and technical problems.

6. Invention and development of devices to serve special needs of the Government.

This general statement of functions of the National Bureau of Standards is supplemented by a more specific list of nineteen activities with the following provisions:

1. The construction of physical standards.

2. The testing, calibration, and certification of standards and standard measuring apparatus.

3. The study and improvement of instruments and methods of measurements.

4. The investigation and testing of railroad track scales, elevator scales, and other scales used in weighing commodities for interstate shipment.

5. Cooperation with the states in securing uniformity in weights and measures laws and methods of inspection.

6. The preparation and distribution of standard samples such as those used in checking chemical analyses, temperature, color, viscosity, heat of combustion, and other basic properties of materials; also the preparation and sale or other distribution of standard instruments, apparatus and materials for calibration of measuring equipment.

7. The development of methods of chemical analysis and synthesis of materials, and the investigation of the properties of rare substances.

8. The study of methods of producing and of measuring high and low temperatures; and the behavior of materials at high and at low temperatures

9. The investigation of radiation, radioactive substances, and X-rays, their uses, and means of protection of persons from their harmful effects.

10. The study of the atomic and molecular structure of the chemical elements, with particular reference to the characteristics of the spectra emitted, the use of spectral observations in determining chemical composition of materials, and the relation of molecular structure to the practical usefulness of materials.

11. The broadcasting of radio signals of standard frequency.

12. The investigation of the conditions which affect the transmission of radio waves from their source to a receiver.

13. The compilation and distribution of information on such transmission of radio waves as a basis for choice of frequencies to be used in radio operations.

14. The study of new technical processes and methods of fabrication of materials in which the Government has a special interest; also the study of methods of measurement and technical processes used in the manufacture of optical glass and pottery, brick, tile, terra cotta, and other clay products.

15. The determination of properties of building materials and structural elements, and encouragement of their standardization and most effective use, including investigation of fire-resisting properties of building materials and conditions under which they may be most efficiently used, and the standardization of types of appliances for fire prevention.

16. Metallurgical research, including study of alloy steels and light metal alloys; investigation of foundry practice, casting, rolling, and forging; prevention of corrosion of metals and alloys; behavior of bearing metals; and development of standards for metals and sands.

17. The operation of a laboratory of applied mathematics.

18. The prosecution of such research in engineering, mathematics, and the physical sciences as may be necessary to obtain basic data pertinent to the functions specified herein.

19. The compilation and publication of general scientific and technical data resulting from the performance of the functions specified herein or from other sources when such data are of importance to scientific or manufacturing interests or to the general public, and are not available elsewhere, including demonstration of the results of the Bureau's work by exhibits or otherwise as may be deemed most effective.

Besides these amendments, the new act adds three sections which refer to financial support for the Bureau's work from sources other than direct appropriations:

1. For all services rendered for other Government agencies by the Secretary in the performance of functions specified herein, the Department of Commerce may be reimbursed in accordance with section 601 of the Economy Act of June 30, 1932.

2. In the absence of specific agreement to the contrary, equipment purchased by the Department of Commerce from transferred or advanced funds in order to carry out an investigation authorized herein for another Government agency shall become the property of the Department of Commerce for use in subsequent investigations.

3. (*a*) The Secretary of Commerce is authorized to accept and utilize gifts or bequests of real or personal property for the purpose of aiding and facilitating the work authorized herein.

(*b*) For the purpose of Federal income, estate, and gift taxes, gifts and bequests accepted by the Secretary of Commerce under the authority of this Act shall be deemed to be gifts and bequests to or for the use of the United States.

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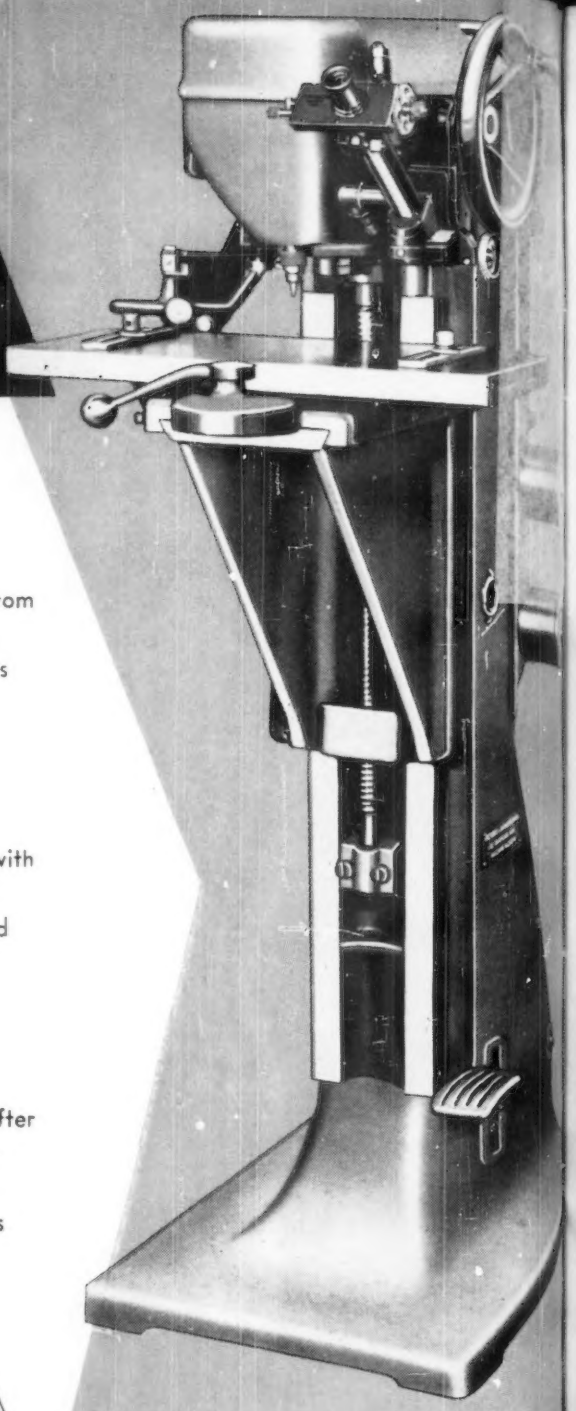

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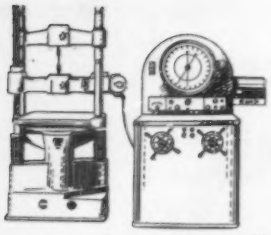

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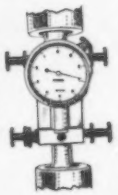

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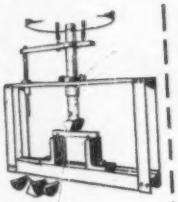

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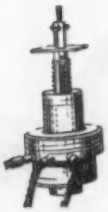

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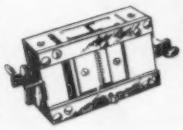

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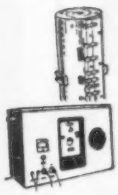

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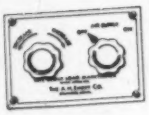

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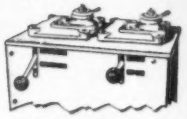

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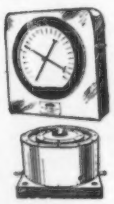

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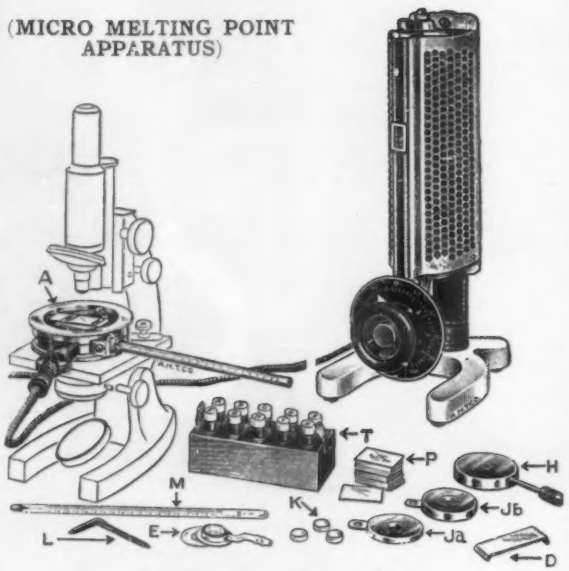

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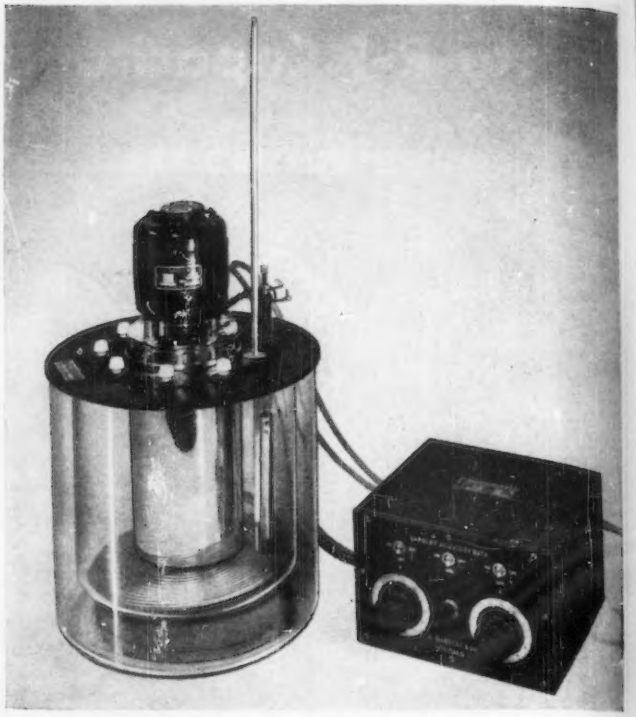

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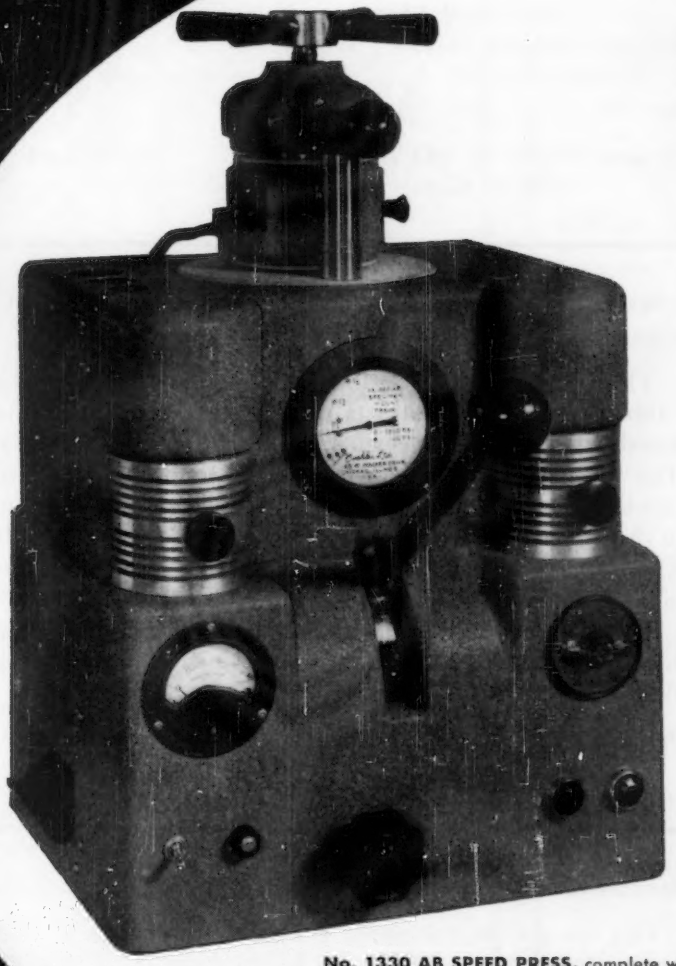

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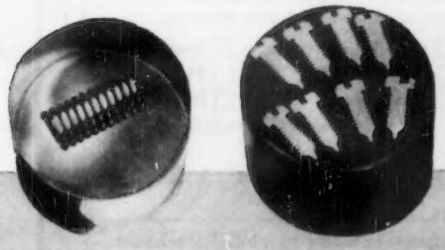

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This symposium represents a review of progress in the field of turbine lubrication. Among the subjects discussed are: the roll of inhibited turbine oils in allowing the operation of turbines for extended periods; selection of inhibited turbine oils; testing to determine the useful life of used inhibited turbine oils; problems due to use of turbine oils at higher temperatures and with lower operating viscosities in gas turbines.

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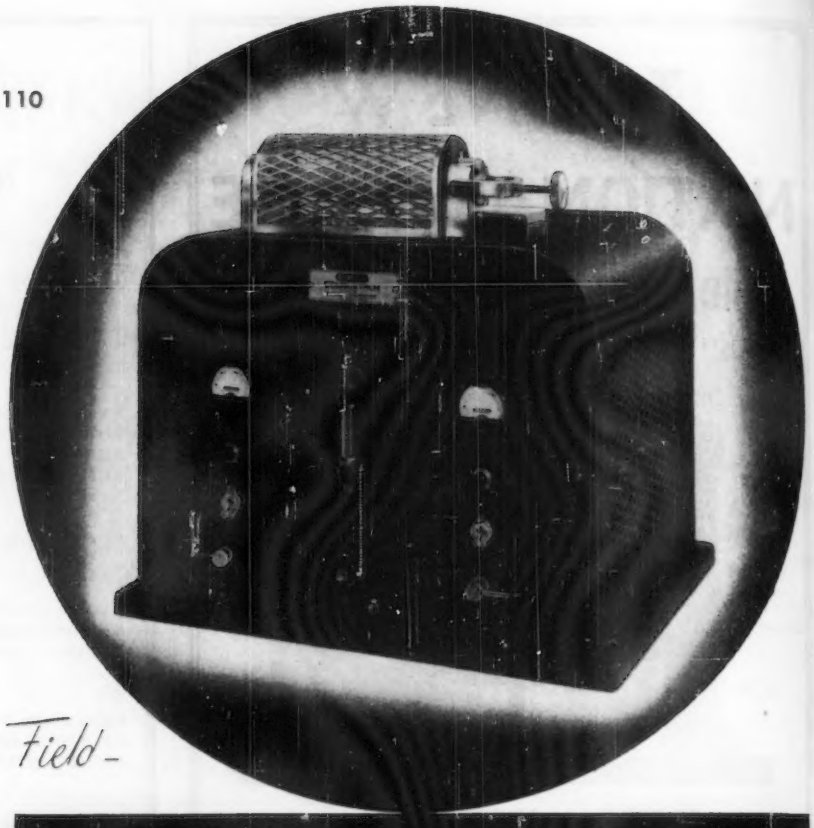

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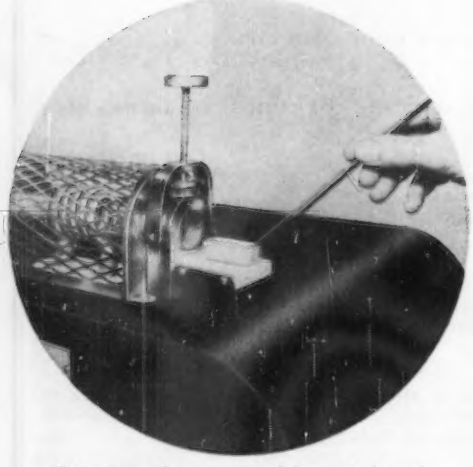

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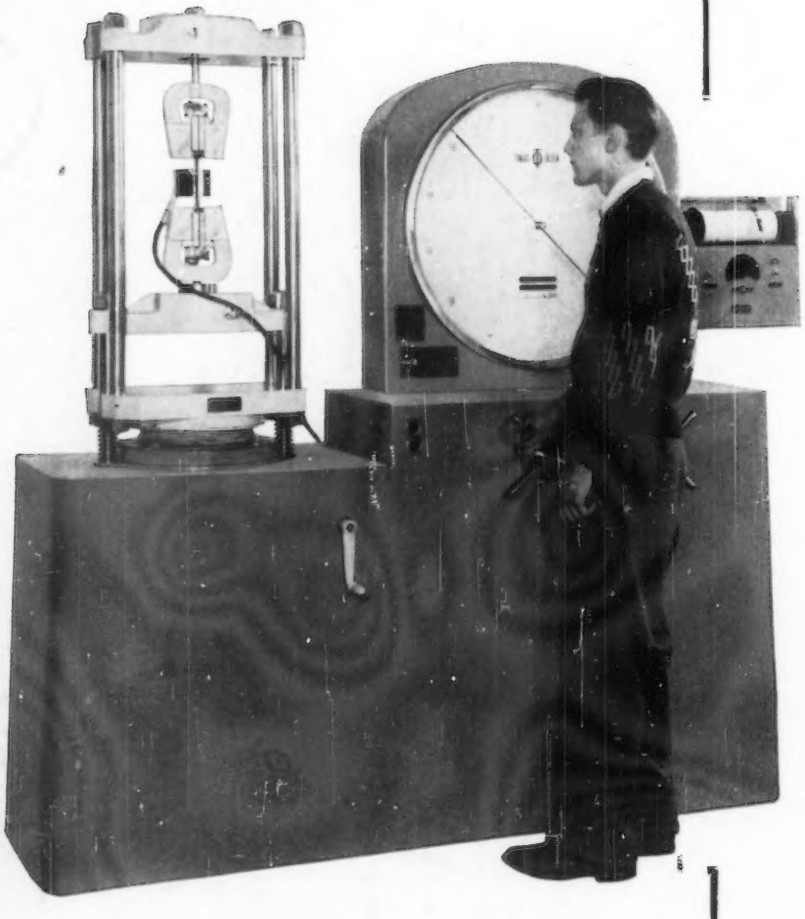

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